"A study on outcome of surgical treatment of compound tibia fractures by intramedullary nailing after preliminary external fixation – short term retrospective and prospective analysis"

Dissertation Submitted For

M.S. DEGREE EXAMINATION

BRANCH - II ORTHOPEDIC SURGERY

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APRIL – 2014

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This is to certify that the dissertation titled **"A study on outcome of surgical treatment of compound tibia fractures – intramedullary nailing after preliminary external fixation – short term retrospective and prospective analysis"** is the original work done by ***Dr. T.Sureshkumar,*** post graduate in M.S., Orthopaedic Surgery at the Institute of Orthopedics and Traumatology, Madras Medical College, Chennai-600003 to be submitted to the Tamil Nadu Dr. M.G.R. Medical University, Chennai- 600 032, towards the partial fulfillment of the requirement for the award of M.S., Degree in Orthopaedic Surgery, April 2014.

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CONTENTS

INTRODUCTION

The tibial shaft is one of the most common sites of an open fracture, a fracture that involves a break in the skin with soft tissues communicating with the fracture or its hematoma, or both. Because of the high prevalence of complications associated with these fractures, management often is difficult, and the optimum method of treatment remains a subject of controversy.

About 23% of all tibial fractures are open and most of these are Gustilo grade III[53]. Most of them are due to road traffic accidents followed by fall, sports activities, blow / assault, gunshot injuries and other rare injuries like blasts.

Open injuries of tibia are associated with twice the amount of contamination than other open fractures. With better understanding of the importance of serial wound debridement and early soft tissue cover for open fracture [18,20] good results have been achieved. Subcutaneous nature of the tibia makes the secondary reconstructive procedures difficult. But the advent of free flaps and advancement made in the micro-vascular techniques have led to reliable cover of traumatic musculocutaneous defects. Progressive refinements in the fixation of fractures and early bone grafting have resulted in a shorter time to union. The combined treatment of both the soft-tissue and skeletal components of severe open tibial fractures by dedicated teams commonly the orthopedic surgeon and plastic surgeon has further improved outcomes and reduced morbidity.

AIM OF THE STUDY

To evaluate the functional outcome of surgical treatment of compound tibia fractures by intramedullary nailing after preliminary external fixation – short term retrospective and prospective analysis.

HISTORICAL REVIEW

Evolution of open fracture management

HIPPOCRATES (460-335 BC) advanced steel and iron in treating the wound that did not progress.

BRUNCHWING AND BOTTELO in 15th – 16th century advocated removal of non-vital tissues.

DESAULT in the 18 century established the making of a deep incision to explore a wound, remove dead tissues and provide drainage, He adopted the word '*DEBRIDEMENT'*, LARRY pupil of Desault contended that sooner. Debridement is done the better the results.

STADER popularized External fixation in domestic animals external fixation gained considerable popularity in the military during II world war. ROGER ANDERSON in the 1950 and early 1960 used their External Fixation frames for open fractures.

VIDAL in 1970 modified HOFFMAN fixators which quickly gained wide popularity in 1970.

LOTTES and BAUBIGNE in 1970 showed excellent results using closed tibial nailing in the treatment of open fractures of tibia.

FISHER and AO groups in 1980 modified and popularized External fixation.

TORNETTA et al in 1997 reported similar incidence of infection and lower rate of malunion in open fractures of tibia treated with undreamed interlocking nailing in comparison with external fixation.

O-BRIEN and colleagues in 1997 reported 4% infection rate in reamed tibial nails and 0% infection in non-reamed tibial nails.

J. F. KEATINGS ET AL. in 1997 in their prospective study no increase infection and nonunion with reamed nailing for open tibial fractures.

J. F. KEATINGS ET AL. in 2000 said that reamed intramedullary nailing is a satisfactory treatment for Gustilo grade-III tibial fractures.

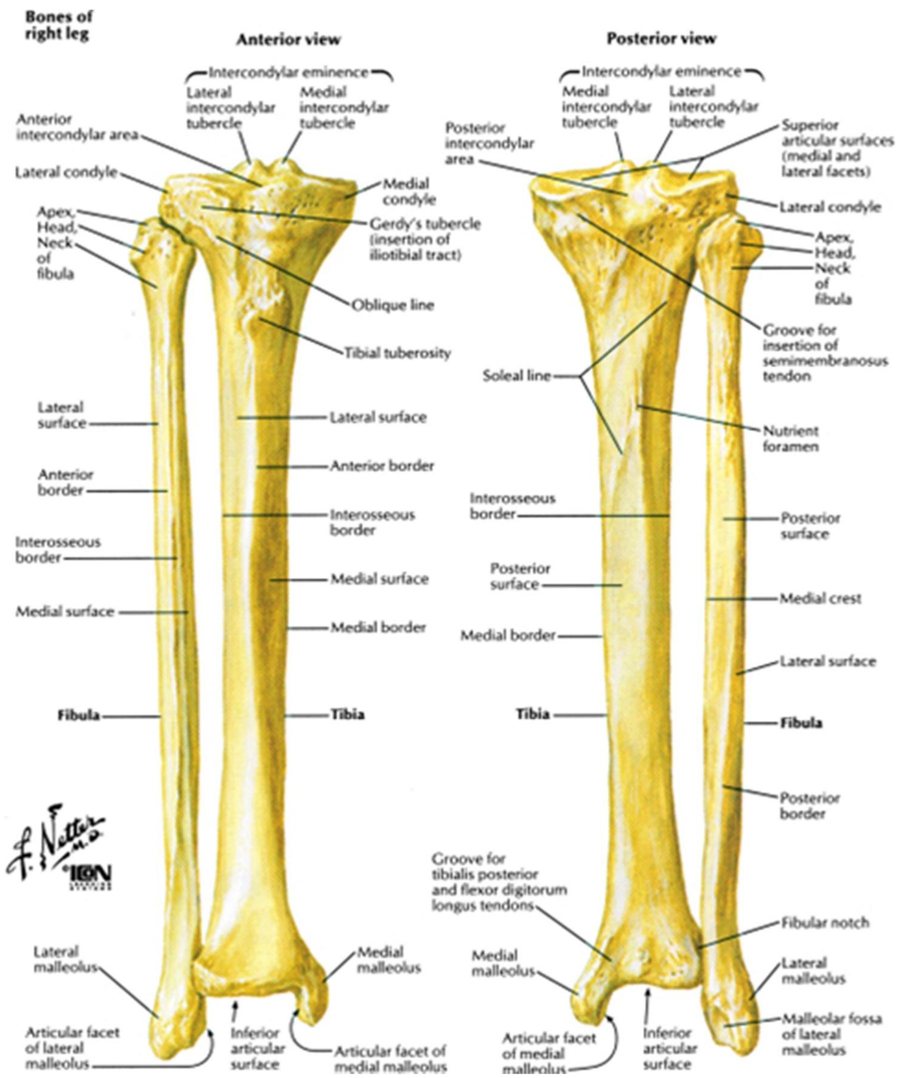
ANATOMY

TIBIA

Tibia serves as a weight bearing support to the body and also a conduit for neurovascular supply of foot. The location of the tibia and the fact that its anteromedial border is subcutaneous renders the bone susceptible to injury. The length of the tibia varies from 30 cm to 47 cm, its diameter from 8 mm to 15 mm. Diaphysis becomes thinner distally, which means that it is particularly at risk from twisting injuries. The medullary canal is significantly more round in cross section than external appearance. It is hour-glass shaped with variably pronounced Isthmus, such that a tight endosteal fit with intramedullary fixation is achieved only in the middle few centimeters of diaphysis.

Proximal tibia has apex angulation averaging 15 degree which requires a bend in the upper portion of medullary nails. Proximal tibial posterior wall is thin and flat which makes it possible to perforate with intramedullary nail. The distal cancellous bone is often compact enough to restrict intramedullary nail penetration. So it is prudent to ream specially for distal fourth fractures, for the IM-nail to reach the desired level. Variably pronounced Isthmus may limit the endosteal contact of intramedullary nail even after significant reaming.

Bones of the right leg



Compartments

A thorough knowledge of both topographical and structural anatomy of leg is essential in planning operative approaches to the extremity. The muscle, tendon, ligament and neurovascular structures in leg are divided into anterior, lateral and posterior compartments. An anterolateral septum divides the lateral compartment from the anterior. A posterolateral septum lies between lateral and superficial posterior compartments. Finally a posterior septum intervenes between the deep and superficial posterior compartments.

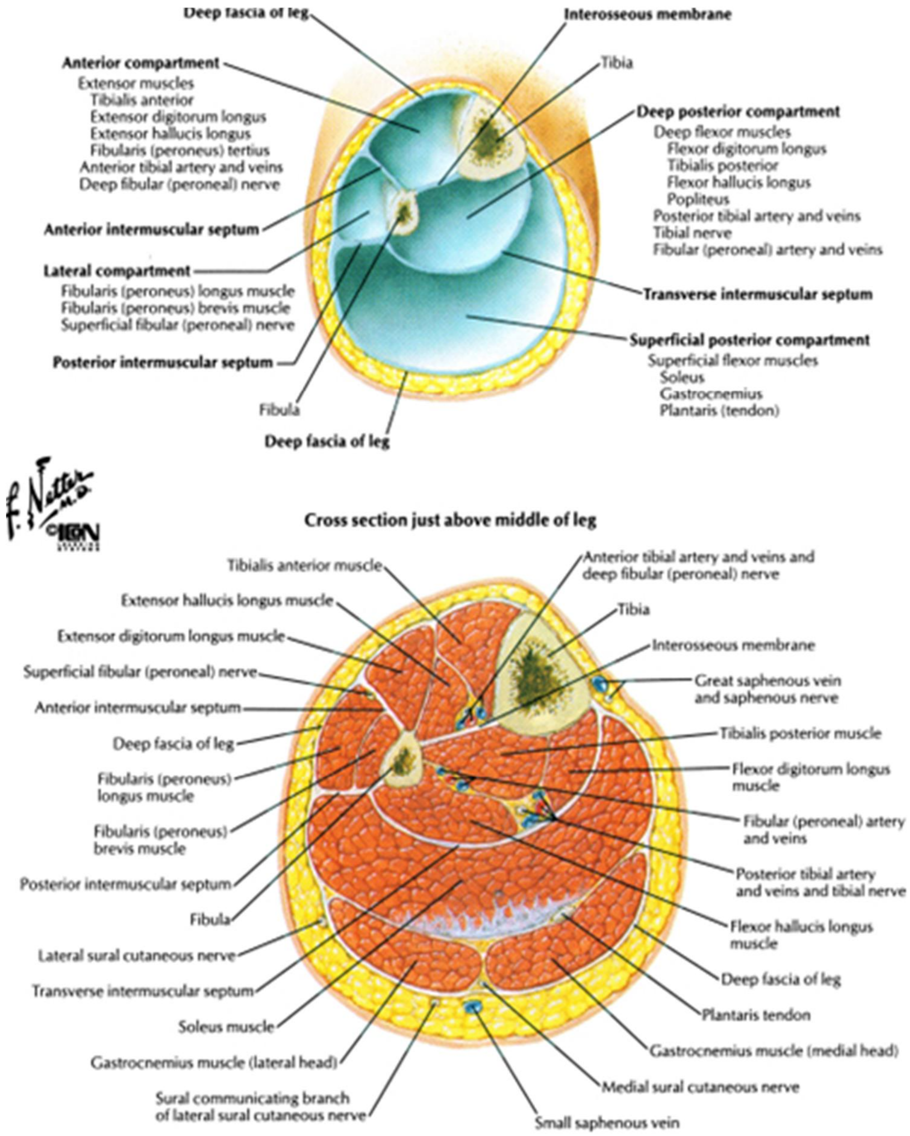
Anterior Compartment

The anterior compartment of the leg contains the tibialis anterior, extensor digitorum longus, extensor hallucis longus, and peroneus tertius muscles. These muscles are enclosed in a relatively unyielding compartment.

The anterior tibial artery and the deep peroneal nerve run deep to the muscles. Near the ankle, the tendons of the tibialis anterior and extensor hallucis longus and extersor digitorum longus are close to the tibia and may be injured by an open fracture of entrapped by callus formed during fracture healing.

Lateral Compartment

The lateral compartment contains only two muscles, the peroneus brevis and peroneus longus. Because of their origin from the proximal and middle fibula, they protect the fibula from direct injury. The superficial peroneal nerve runs the between the peroneal muscles and the extensor digitorum longus.



Superficial Posterior Compartment

The superficial posterior compartment contains the gastrocnemius, the soleus, the popliteus, and the plantaris muscles. A sensory nerve, the sural nerve, and the short and long saphenous veins are also within this compartment, but there are no arterial structures of significance. This compartment also serves as a source of local muscle flaps for coverage of soft-tissue defects in the proximal and middle third of the tibia.

Deep Posterior Compartment

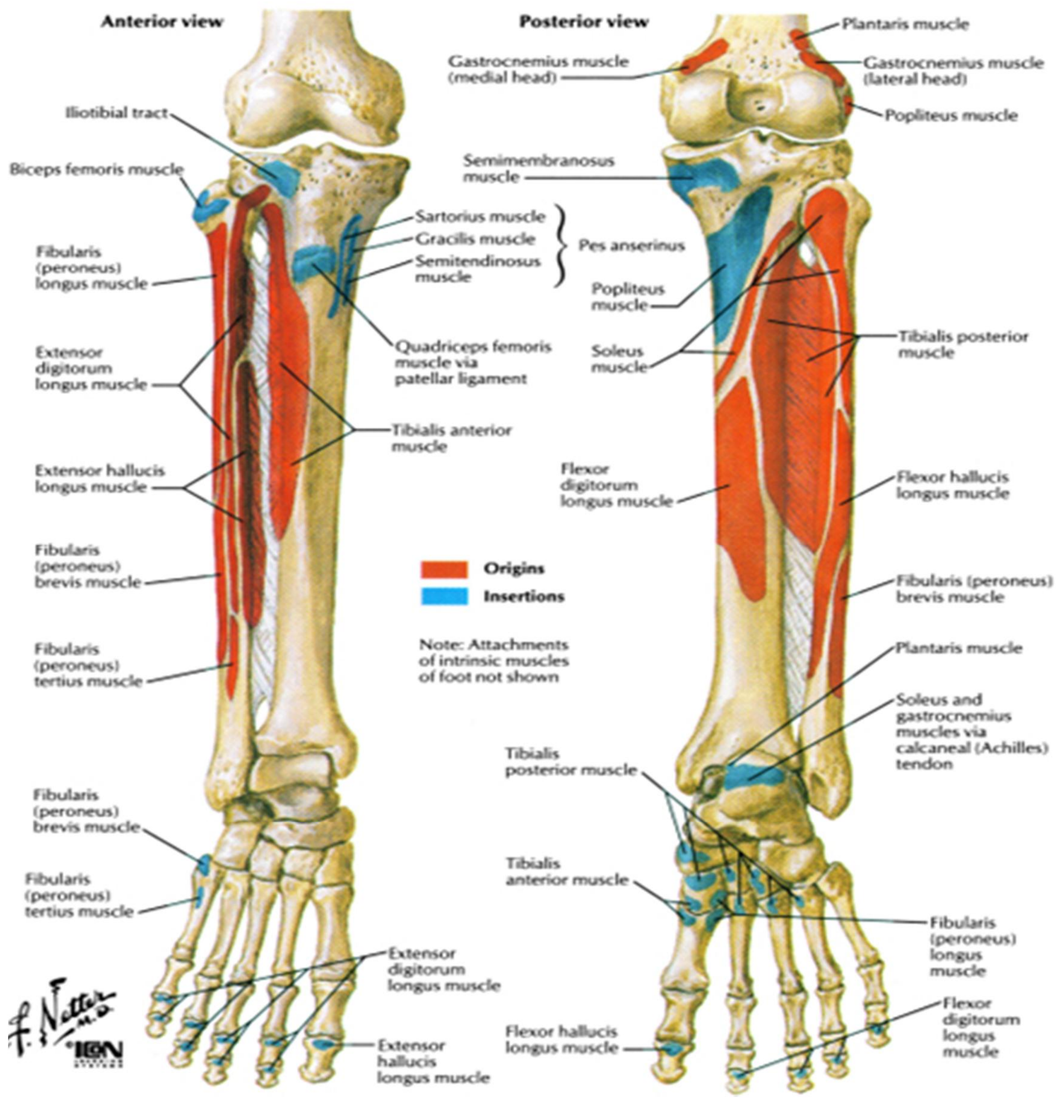
The deep posterior compartment contains the tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles. The major neurologic structure is the posterior tibial nerve. Two major arteries, are present in this compartment. The posterior tibial artery, because of its protected nature, frequently is the major arterial supply after a significant open fracture and is a potential source for anastomosis with free flaps for soft-tissue reconstruction of the leg.

Blood Supply

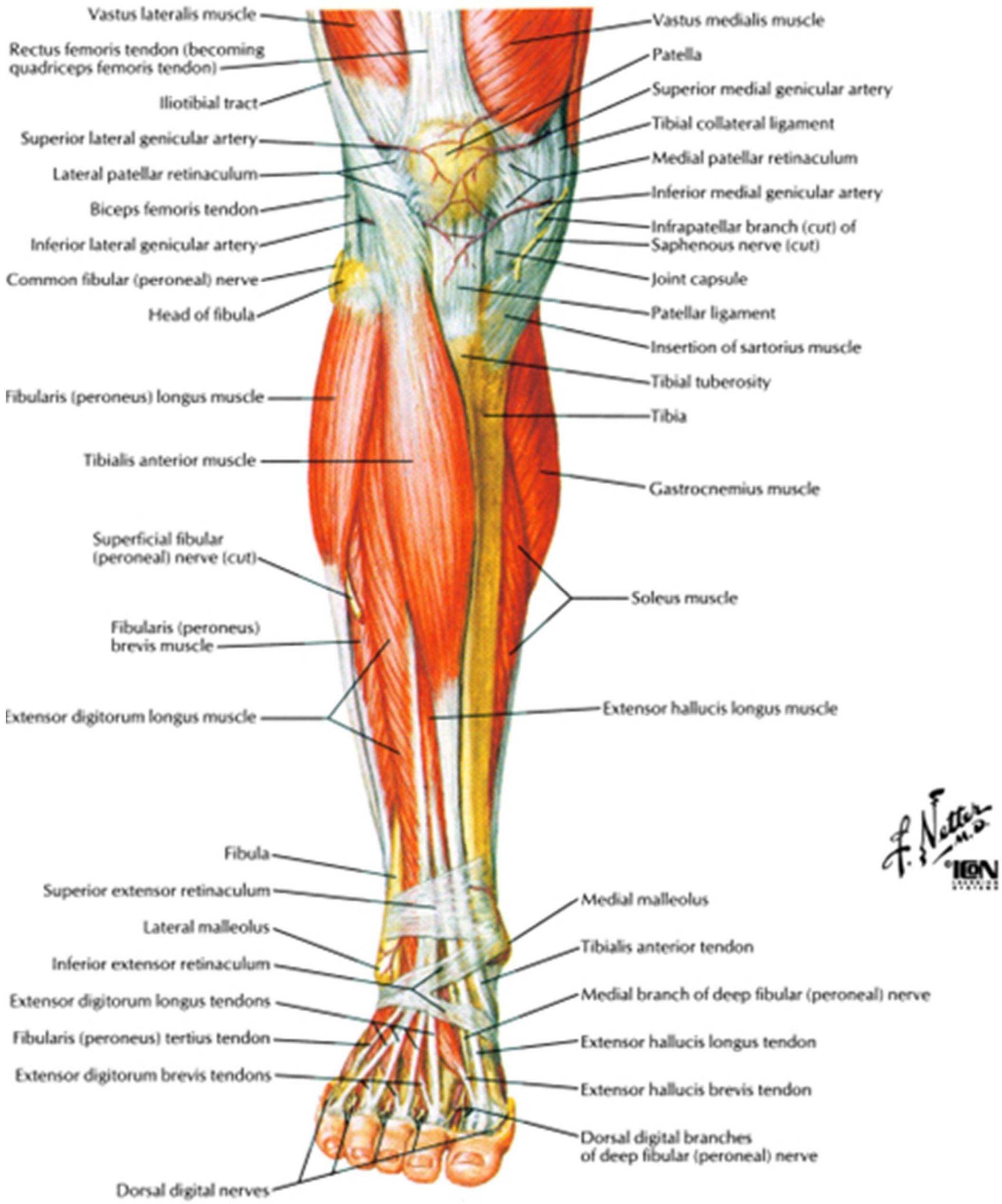
The Blood supply of the tibial shaft is derived from the nutrient artery and the periosteal vessels. The nutrient artery of the tibia arises from the posterior tibial artery and enters posterolateral cortex of the bone at the origin of the soleus muscle just below the oblique line of the tibia posteriorly. The artery may traverse a distance of 5.5 cm before entering its oblique nutrient canal. This artery divides into three ascending branches and only one main descending branch, which give off smaller branches to the endosteal surface. While the descending nutrient artery reaches the junction of the middle 3rd and lower 3rd, it is almost exhausted of its supply rendering lower 3rd relatively a vascular.

The periosteum has an abundant blood supply from branches of the anterior tibial artery and posterior tibial artery as it courses down the interosseous membrane. The role of each source in fracture healing is controversial. It nourishes the outer one-fifth to one-third of the cortical bone. Nelson and colleagues believe that the periosteal blood supply plays a relatively minor role in supplying the normal adult tibial cortex.

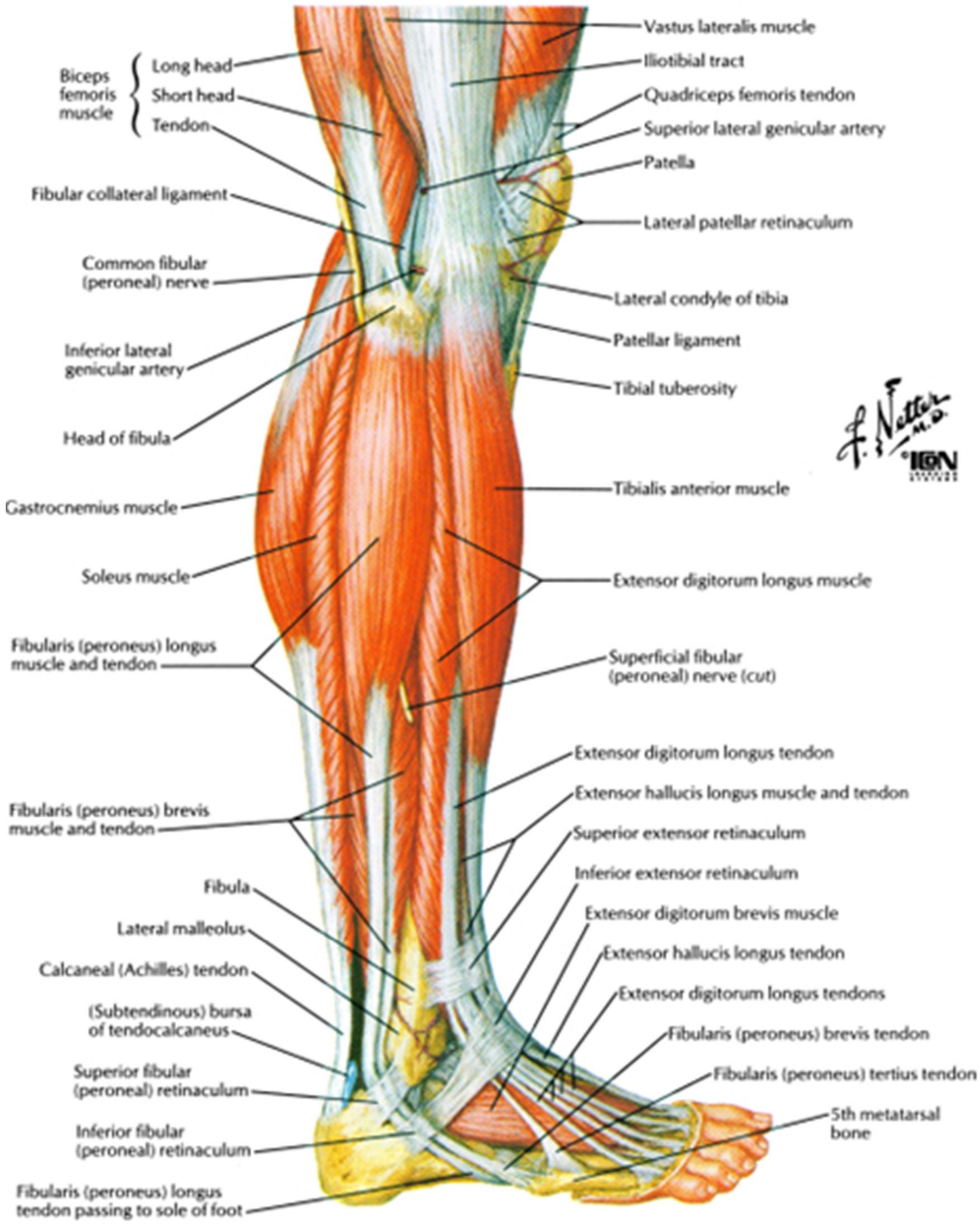
Muscular attachment (Origin & Insertion)



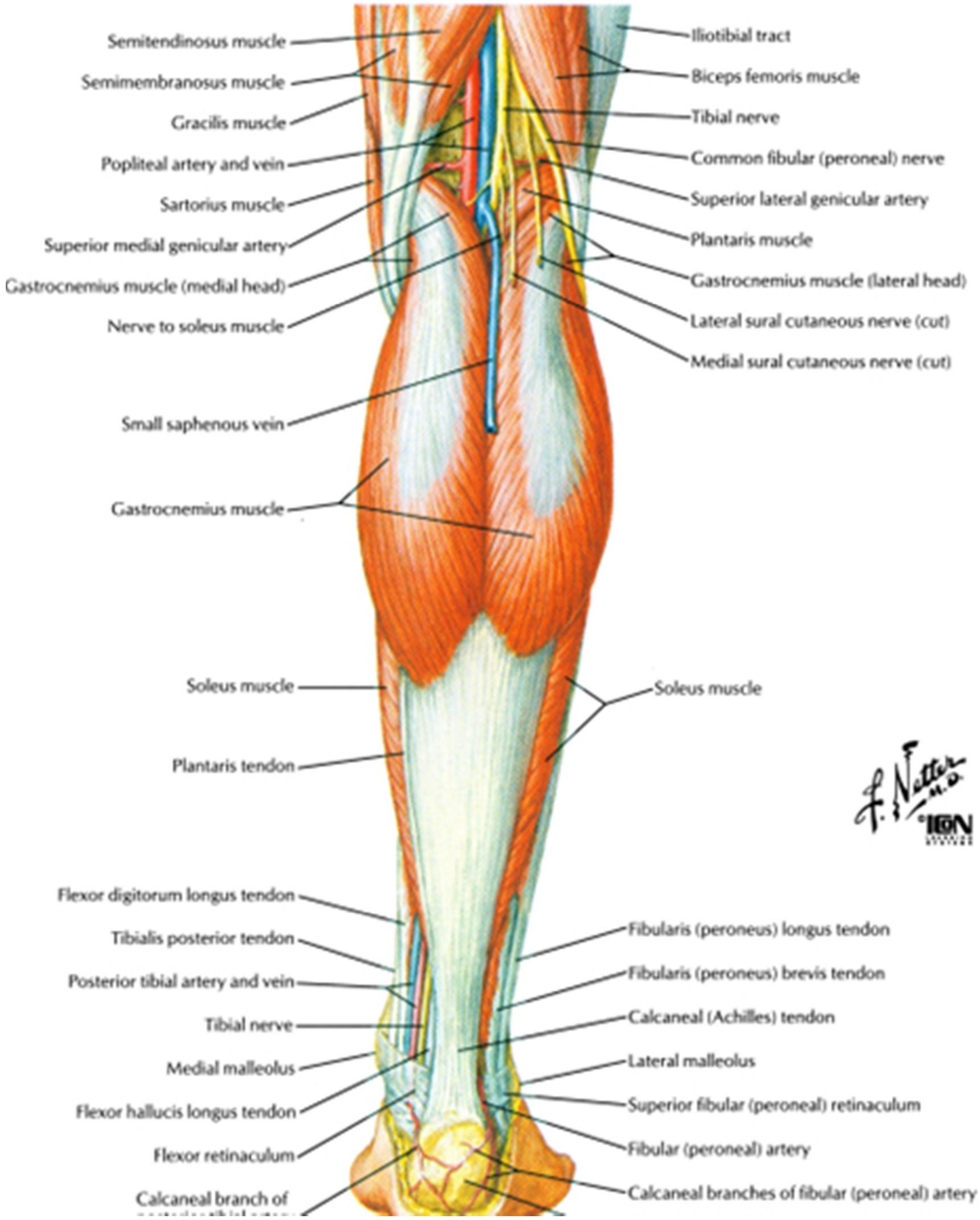
Anterior compartment



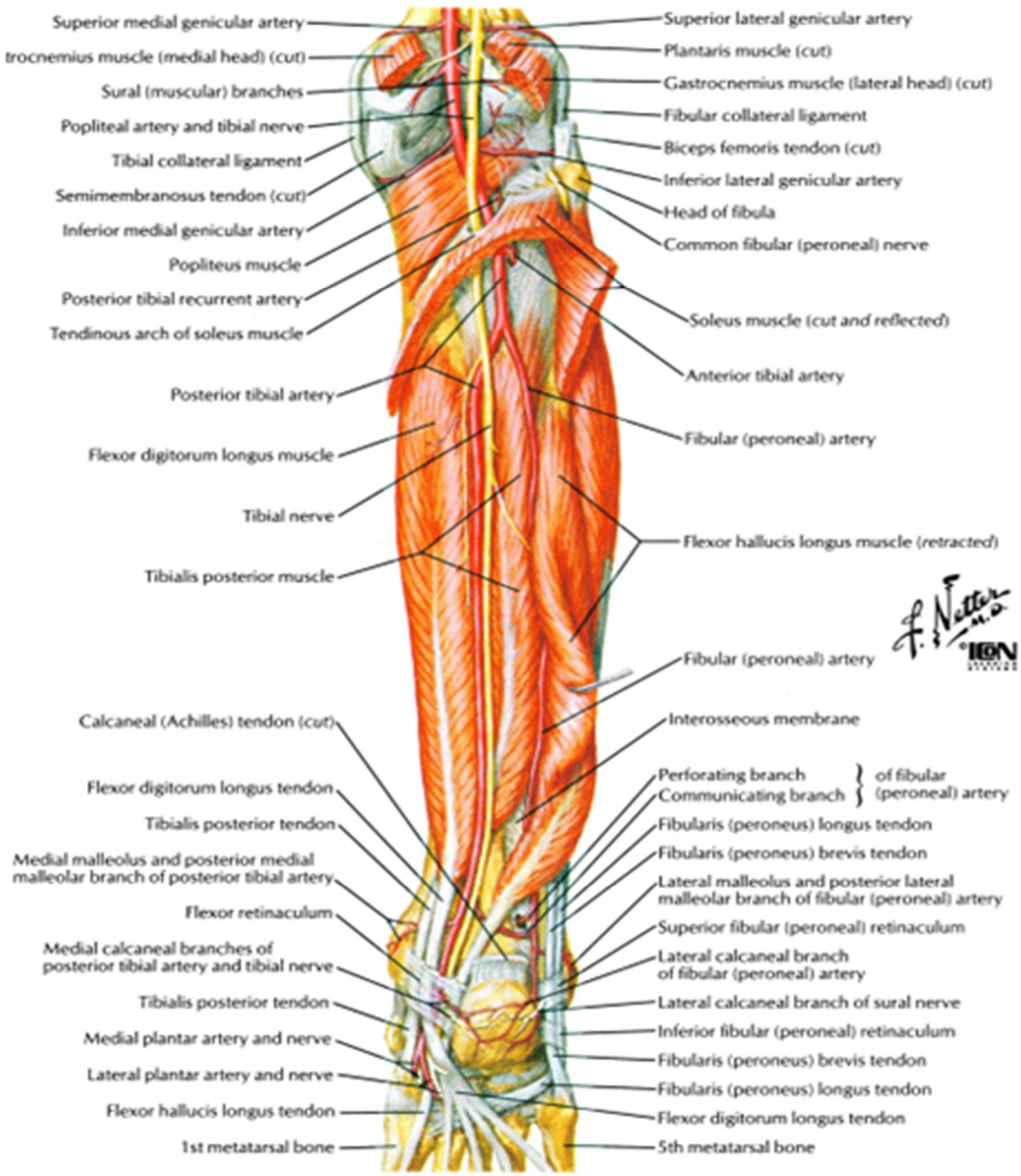
Lateral compartment



Posterior compartment & neurovascular supply



Deep posterior compartment & neurovascular compartment



Rhinelander also stated that the intramedullary vascular supply is the most important in normal bone; however, after an injury that disrupts the intramedullaryvascular pattern, the periosteal blood vessels increase their contribution and become prominent in the formation of new bone. Macnab and de Haas found that the periosteal vessels were especially important in distal third tibial fractures but found no difference in intramedullary supply between proximal and distal regions.

The concerns for the effect of reaming in intramedullary nailing of open tibial fractures have led to the use of unreamed nailing for open fractures of tibia. Most researchers have shown a shorter time for revascularization of the endosteum with nonreamed versus reamed techniques, but the clinical advantages of this concept are still a subject for debate since it does not affect fracture healing.

MICROBIOLOGY[55,56]

Sixty percent of open fracture wounds are contaminated with bacteria at the time of injury. Most infections in open fracture are nosocomial. Most infecting organism are found to be enteric flora rather than normal skin flora. Organisms causing infections in open tibial fracture are Psedomanas aeruginosa, Aeromonas species, Methicillin resistant Staphllococus aureus (MRSA) or their combinations.

Only 18% of predebridement swabs eventually become infected. However none of the organisms, which grew in thee predebridement culture, caused later infection. A negative predebridement culture did not preclude infection as 6% of the open fractures became infected [55].

Intraoperative cultures of tissues and marrow are of no help in determining causative organisms, as none of the intraoperative bacteria cultures eventually causing infection [55].

Postoperative culture results are more representative. Seventy five percent of cases with positive post debridement cultures eventually develop infection and in 50% cases, similar types of organisms are isolated [55].

Contaminant bacteria are mainly of gram positive cocci, mainly Staphylococcus aureus and Staphylococcus epidedermis [55].

For detecting infection, predebridement cultures have better sensitivity, while postdedbridement cultures have better specificity [56].

CLASSIFICATION

Open wounds have been classified several ways. Gustilo and Anderson in 1976 described open fractures with application of a grading system that offered prognostic information about the outcome of infected fractures.

In 1984, this system was modified. The modified classification is based on the size of the wound, periosteal soft-tissue damage, periosteal stripping, and vascular injury.

In **Type I** open fractures have a clean wound less than 1 cm long.

In **type II** fractures, the laceration is more than 1 cm long, but there is no extensive soft-tissue damage, skin flaps, or avulsions.

In **Type IIIA** open fractures have extensive soft-tissue lacerations or flaps, but maintain adequate soft-tissue coverage of bone, or they result from high-energy trauma regardless of the size of the wound. This group includes segmental or severely comminuted fractures, even those with 1-cm lacerations.

Type IIIB open fractures have extensive soft-tissue loss with periosteal stripping and bony exposure. They usually are massively contaminated.

Type IIIC open fractures include open fractures with an arterial injury that requires repair regardless of the size of the soft-tissue wound.

This classification has prognostic significance

GULSTILO ANDERSON CLASSIFICATION

Grade I open fracture

Grade II Open fracture

Grade III A open fracture

Grade III B Open fracture

Grade III C Open fracture

Other classifications.

Tscherne Classification for Open Tibial Fractures

Grade 1	Skin lacerations caused by a bone fragment from inside, little or no contusion of skin
Grade 2	Any type of skin laceration with circumscribed skin or soft-tissue contusion and moderate contamination; can occur with any type of fracture
Grade 3	Fracture must have severe soft-tissue damage, often with major vessel or nerve injury or both: all fractures accompanied by ischemia and severe bone comminution belong in this group and those associated with compartment syndrome
Grade 4	Subtotal and total amputation, defined as separation of all important anatomical structures, especially major vessels with total ischemia; remaining soft tissue may not exceed one fourth of circumference of extremity (any revascularization is grade 3)

The AO-ASIF group

This added to their extensive fracture classification a soft-tissue classification scheme that closely follows that of Tscherne

This classification includes closed (C) and open (O) injuries, muscle-tendon injury (MT), and neurovascular injury (NV).

Swiontkowski et al., in an evaluation of the AO/OTA fracture classification system, found that patients with C-type fractures had significantly worse functional performance and impairment compared with patients with B-type fractures, but were not significantly different from patients with A-type fractures. They concluded that the AO/OTA classification may not be a good predictor of functional performance and impairment in patients who have isolated unilateral lower extremity fractures.

AO-ASIF Soft-Tissue Injury Classification	
Scale	
1	Normal (except open fractures)
2-4	Increasing severity of lesion
5	A special situation
Skin Lesions (Closed Fractures)	
IC 1	No skin lesion
IC 2	No skin laceration, but contusion
IC 3	Circumferential degloving
IC 4	Extensive, closed degloving
IC 5	Necrosis from contusion
Skin Lesions (Open Fractures)	
IO 1	Skin breakage from inside out
IO 2	Skin breakage <5 cm, edges contused
IO 3	Skin breakage >5 cm, devitalized edges
IO 4	Full-thickness contusion, avulsion, soft-tissue defect, muscle-tendon injury

Muscle-Tendon Injury	
MT1	No muscle injury
MT2	Circumferential injury, one compartment only
MT3	Considerable injury, two compartments
MT4	Muscle defect, tendon laceration, extensive contusion
MT5	Compartment syndrome/crush injury
Neurovascular Injury	
NV1	No neurovascular injury
NV2	Isolated nerve injury
NV3	Localized vascular injury
NV4	Extensive segmental vascular injury
NV5	Combined neurovascular injury, including subtotal or complete amputation

Injury severity scoring is another area of classification. These systems attempt to evaluate the severity of multiple injuries and their effect on survival of the patient or the degree of later disability.

Most of these systems consider the musculoskeletal system as one number regardless of the number of bones broken.

Many do not take into account injuries to the soft tissues of the extremities. These systems include

- the Trauma Score (TS);
- Revised Trauma Score (RTS);
- Injury Severity Score (ISS);
- Modified Abbreviated Injury Severity (MISS);
- Pediatric Trauma Score (PTS);
- Nerve Injury, Ischemia, Soft-Tissue Injury, Skeletal Injury, Shock, and Age of Patient Score (NISSSA); and
- Hanover Fracture Scale-97 (HFS-97).

Many of these systems are used to compare the degree of injury with damage at the scene of the accident for the purpose of evaluating motor vehicle safety features and improving them.

MANAGEMENT

Resuscitation

Open fracture [14,23,37,38] is an operative emergency about 20% of the patients may have associated abdominal, chest and head injuries. All trauma patients are managed according to guide lines given by ATLS. During resuscitation wound is covered and extremities are splinted.

Assessment of extremity

Once the patient becomes stable, thorough circumferential inspection and palpation should be done. During the examination brief history is sought. Wound is thoroughly examined for size, site, skin loss, periosteal stripping and bone loss. Contamination, Neurovascular status of the extremity and compartment syndrome must be specifically looked for.

Foreign bodies or any obvious debris like leaves grass or stones should be removed with sterile forceps. If the patient can be taken up for the surgery within one or two hours, wound can be covered with sterile dressings. If the timing is uncertain irrigate the wound with one or two litres of saline before placing the sterile dressing. Once the sterile dressing is placed no further wound examination is done until the patient is in the operating room.

Patient must have the open fractures irrigated, covered with sterile dressings, and splinted before going for x rays.

Tetanus status of the patient should be sought and if necessary tetanus immunoglobulin should be given. Good quality AP and lateral X rays of the fracture including knee and ankle is necessary. Facture pattern displacement degree of comminution and the joint involvement can be studied. Radio opaque foreign bodies may be seen. Air trapped in the soft tissues may indicate severe degloving injury X-rays are essential to decide the method of fixation.

Antibiotic therapy

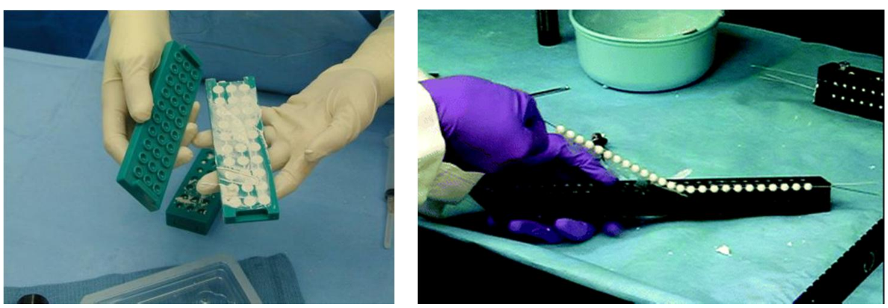
Currently routine use of cultures either before or after debridement is not recommended since most of the time cultured organisms are not the cause of infection. Most of the infection in open fractures are caused by gram negative rods and gram positive staphylococci.

There is currently controversy with regard to the specific antibiotic to be given after open fracture. Generally an antibiotic with broad spectrum gram positive coverage usually a first generation cephalosporin like cefazolin is given for grade I and grade II. An aminoglycoside like gentamicin / amikacin is added for grade III fractures depending on the renal parameters. Pencillin or metronidozole is added when there is organic contamination. But there is no specific antibiotic regimen commonly antibiotics are administered till 24 Hours after the wound closure. Antibiotic should be initiated as soon as possible following injury since it decreases rate of infection.

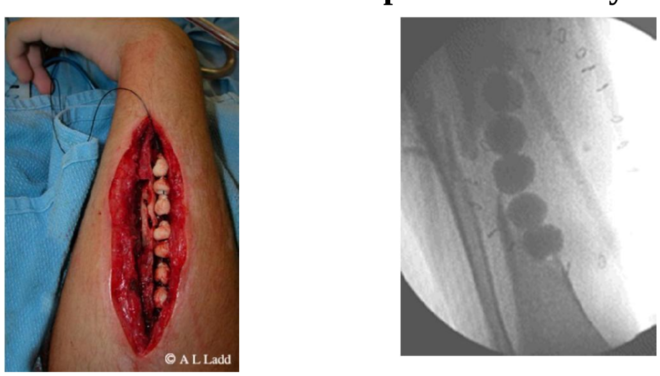
Local Antibiotic Therapy

The systemic side effects are reduced by the local antibiotic therapy as it also generates high antibiotic concentration within the wound. Then comes the appropriate choice for selecting the agents, should be heat stable, available in powder form, and active against suspected pathogens. The drugs meeting these criteria are aminoglycosides and vancomycin. Antibiotics are delivered locally by the technique called **bead pouch technique** in which antibiotic mixed with poly methyl methacrylate are made into beads (< 6mm diameter), string with stainless wire.

Preparation of antibiotic bead:



Placement of antibiotic bead pouch and x ray image:



Debridement & Classification of the injury

For open fracture, emergency operative treatment has long been the standard. Recent studies have questioned the value of six hour rule insisted on thorough operative treatment even for open fractures of low grade severity. The timeliness of the soft tissue coverage and adequacy of debridement are more important than the time from injury to debridement in the prevention of infection after open fractures.

Preparation

Open fractures are often present unexpected surprises. Therefore, a full set of soft tissue and bone instruments must be made available. The full assortment of fixation devices that might be necessary to stabilize the fracture must be available. On table, splints and dressings are removed. A thorough surgical preparation is done with gentle traction of the limb.

Tourniquet should be available. For severely contaminated wounds two phase preparation is advised. With one preparation set, toes upto the tourniquet is washed. A liter of saline is poured over the wound. With the second preparation set a formal surgical preparation of the extremity is performed.

Debridement

Open tibial fracture debridement includes operative exploration of the wound, defining the zone of injury, removing devitalized tissues. Sharp dissection done and the wound extended at both the ends until healthy tissue is seen at both the ends. Systematic exploration of the wound should be done so that a complete debridement of all contaminants and devitalized tissue done. Debridement starts with the skin. After debridement and operative extension the edges of the wound is carefully examined. The indicator of high energy trauma are the evidence of skin and subcutaneous tissue which was avulsed from the underlying fascial and it should be carefully noted as it may be the only indicator of underlying muscle injury.

The methodical way of debridement includes careful inspection of the subcutaneous tissue, muscles and then finally the bones so that overlooking of any devitalized tissue is avoided. First entire extent of the wound inspected for any skin and subcutaneous tissue injury. Crushed and obviously nonviable skin is excised. Skin with doubtful viability is retained and can be checked in next debridement. And this is mainly done in subcutaneous borders of the tibia, where excessive removal of the skin will result in a need to put a local or distant flap to cover the bone. No marginally viable fascia is to be left out. Limited fasciotomy should be done in all open fracture secondary to high energy fractures and it also helps in assessing the underlying muscle compartment. It should be done always as part of debridement. The **four C's of muscle viability** checked for, that is **c**olor, **c**onsistency, **c**ontractility, and **c**apacity to bleed. Muscles should be carefully checked for this. Of the four, the last two, mainly the contractility, is the most sensitive indicator of muscle viability. The weakly contractile muscle and the one that is contused can be left and again re inspected after twenty four to forty eight hours. Without compromising the debridement, wherever possible, the integrity of the musculotendinous units are maintained. Since that if even 10% of a muscle belly and its attached tendon can be preserved significant function is retained.

Tendons unless obviously severely damaged and contaminated is preserved. Preservation of peritenon is essential for tendon survival and do not debride the peritenon but rather copiously irrigate it.

Bone becomes necrotic when it is stripped of all its soft tissue attachments and causes infection very easily. Avascular segments of bone, small to moderate shall be removed. Making a decision to debride larger portions of devascularized diaphyseal or metaphyseal bone, or both will be a hard task. Retaining of the major articular segments of the tibial plateau and the tibial plafond is done even when there is excessive stripping, if the surgeon believes that the salvage of the involved joint is possible.

If the periosteum stripped area of the bone is in continuity with a portion of the vascularised tibia, it may be retained, if there is adequate soft tissue coverage to allow early revascularization.

At this juncture wound should be classified, accordingly appropriate method of skeletal stabilization should be done.

Irrigation

In open fracture, every effort is taken to irrigate the wound to avoid infection. Decreasing the bacterial load and the foreign particles is the main purpose of the irrigation. Copious amount of irrigation preferably 9 liters of normal saline[10] for grade I to grade III A open fracture. Additional 3 liter is added for more severe fracture. But the evidence to support the volume of the irrigation fluid is very scanty.

Skeletal stabilization

Cast Application

A cast with window makes immobilization as well as minor soft tissue wound management for minimal to moderately displaced fractures up to type II open fractures. It makes the situation very difficult with dressing for major soft tissue wound with simple fracture inside.

External Fixation

Earlier this was the method of choice for open fractures of tibia.

It is still an excellent preliminary procedure for grossly contaminated grade III compound fracture and also used as temporary skeletal stabilizers until definitely procedure undertaken. External fixation[39] is typically applied as a non dynamic (static) form of stabilizing fracture fragments. Newer versions of external fixation (Eg., LRS) allow compression of the fracture site with weight bearing.

Commonly uniplanar or circular external fixator is used. Ortho fix and circular external fixator can be used as definitive fixation for some compound fractures.

Advantages are easy to apply, easy wound toileting, less deep infection. But has several disadvantages like Pin tract infection and conversion to another form of treatment is necessary since pins get loosened with 3-6 months of life span. Prevalence of infection with delayed conversion to IM nail is decreased by early intervention. Early secondary intramedullary nailing within 2 – 3 weeks resulted in good results with better initial soft tissue treatment.

External fixator devices

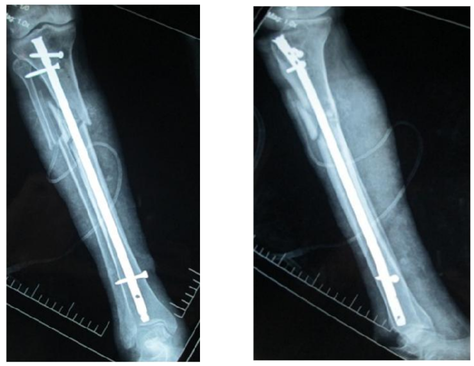
Only with development of mechanically sound devices has external fixation offered a reliable alternative to internal fixation in complex fractures. The AO/ASIF tubular system is light weight, consists of few components only and provides sufficient versatility and stability for successful treatment

Indications

- ❖ Stabilization and correction of extremity misalignment and length discrepancies in severe open fractures and infected non unions.
- ❖ Initial stabilization of bony disruption and soft tissue injuries in poytrauma patients.
- ❖ Multifragmentary diaphyseal and periarticular lesions.

Interlocking nailing

Stabilization with IL nailing[6] has become increasingly popular for treatment of open fracture tibia. The use of reaming [26,28], in the treatment of open fractures continues to be a source of debate. But recent studies suggest that adequate stability is provided by minimum of 10mm size intramedullary nail and recommends at least minimal reaming to accommodate ten size nail. Interlocking nailing is preferred for Grade I, Grade II and Grade III fractures.



In type grade III open fractures fixation should be decided between nailing and external fixation in concordance with degree of contamination, soft tissue defects and feasibility of early reconstruction.

Wound management

Historically, delaying the closure of open fracture wounds is practiced to reduce the infection with clostridium and other common contaminating virulent organisms. But the recent studies have documented significantly better outcome with the early closure [18,19,20,49] than with the late closure in which nosocomial organisms are the main source of infection. Now delayed closure is reserved for wounds with substantial contamination like barnyard and battlefield injuries.

There are several methods to achieve the closure. It includes direct suturing, split thickness skin grafting (SSG), fascio cutaneous flap, free or rotational muscle flaps. With fascio cutaneous flap coverage a segment of the skin, the underlying subcutaneous tissue, and fascia are mobilized to cover the exposed bone or tendon, or both.

Fasciocutaneous flaps are based on circulation from the posterior tibial or peroneal systems. With careful planning a flap with as high as a 3:1 length to width ratio can be created safely while ratio is necessary for random flaps.

In general , tissue defects in the proximal third of the tibia are covered with a gastrocnemius rotational flap.

A soleus rotational flap is recommended for defects in the middle third of the tibial shaft and a free vascularized muscle flap typically is needed for those in the distal third of the tibia.

Recently **vacuum assisted closure** [21,35] **(V.A.C)** has emerged as a useful method of accelerating wound healing by reducing chronic edema, increasing local blood flow and enhancing granulation tissue formation.

The vacuum assisted closure (VAC) device is typically applied at the end of the each irrigation and debridement until the wound is considered clean. Vacuum assisted closure is used for an average of 10 -20 days.

Supplemental procedures

1. Dynamisation

Delayed union can be treated by removal of either proximal or distal interlocking screws (dynamization) of the longest bone segment to allow axial impaction of the fracture, micromovement and stimulate healing. The screws (either proximal or distal) considered least crucial for fracture stability are removed.

This procedure should be considered at 3 months in fractures with minimal callus and is most appropriate for axially stable diaphyseal fractures.· If this has to work there should be adequate space before tip of the nail hitches against the subchondral bone and there should [27] not be new bone formation in the screw holes that were left out are at the tip of the nail. Loss of reduction is one of the rare complication after dynamization that should be kept in mind[29,30,52].

2. Fibular osteotomy

When Dynamic locked nails are used, partial fibulectomy[12] can be done to facilitate impaction of the fracture upon weight bearing or Dynamization can be combined with fibular osteotomy for collapsing of the fracture ends in the cases of delayed union.

3. Exchange nailing

Exchange nailing [7,9] refers to the practice of removing an intramedullary nail from the tibia, reaming the intramedullary canal, and then inserting a larger nail. If a reamed nail has been used primarily the canal should be reamed so that a nail of 1mm more in diameter can be inserted. If the canal is particularly wide then a larger nail will be required, and the surgeon should ream until endosteal bone is seen on the reamers. If an unreamed nail was used primarily, it is wise to ream the canal to allow the insertion of a 10 or 11 mm nail. Commonly done after three – four months where there is minimal callus dynamically locked nails. This can be repeated after 5 -6 months if there is no progression of union. Antibiotic coated exchange nailing can be done for infected non unions. It can be combined with wound debridement and bone grafting if there is only minimal infection. Posterolateral grafting can be combined with exchange nailing for treating infected non unions.

4. Bone grafting

Early bone grafting is done prophylactically within 12 weeks after injury and also try to avoid grafting within two weeks of wound closure. It is done when more than 50% cortical contact bone loss in open fractures. Therapeutic bone grafting is done at 3 months when there is no progression of union.

Posterolateral bone grafting is done for severe bone loss, scaring or sinus at the anterior aspect. Repeated bone grafting may be necessary to achieve union.

The use of recombinant human bone morphogenetic protein-2 (BMP – 2) to promote healing has emerged recently.

Post operative protocol

Quadriceps drill is started in the next day of surgery. Knee and ankle exercise also started on the first postoperative day. The resistive exercises are started after 6 to 8 weeks.

The weight bearing depends on the fracture configuration. Patient with stable fracture type can be allowed touchdown weight bearing in few days after the fracture fixation when the pain and inflammation has been subsided. But patients with unstable comminuted fracture patterns must be allowed weight bear only after adequate callus formation. Patients with segmental fracture allowed to weight bear only after adequate callus formation. Vocational rehabilitation must be a part of compound fracture management.

BIOMECHANICS

Intramedullary nail act as load sharing internal splints when placed in a fractured long bone. The stability offered by the IM nail determined by nail site, number of locking screws and distance of the locking screw from the fracture side.

In current practice with reaming of the canal and the use of locking screws loads are transmitted to the either ends of the nail through the screws. the resistance to motion is determined by the nail within the medullary canal. This in turn is affected by curvature of the nail, cross section of the nail and diameter as well as corresponding properties of the canal.

Three Types of load act on IM nail: Torsion, compression and tension. On physiological loading when the cortical contact across the fracture site is achieved, most of the compressive loads are borne by the cortex. In the absence of cortical contact compressive loads are transferred to the locking screws. Implant failure occurs when the healing is delayed. Locked nails fail by screw breakage and nail breakage at locking hole site. Nails are usually made of Titanium Alloy (or) 316L Stainless Steel. Although there are measurable differences between these two in modular property, the clinical results with either material appear to be equivalent.

Cross section shape of the nail affects its tensional rigidity and amount of contact within the medullary canal. Nail diameter affects bending rigidity and torsional rigidity. Fracture of the long bone fixed with IL nails have 75% of bending rigidity of intact bone. Translation and rotation at the fracture site is restricted by the interlocking screws placed proximal and distal to the fracture site.

However minor movements occur between the nail and the screws allowing toggling of the bone. Placing the screws in multiple planes may reduce the toggle. Diameter of the locking screws also determines the stability, especially when immediate weight bearing is planned. Number of locking screws is determined by location and the stability of the fracture.

Nailing may be static or dynamic. A Statically locked nail doesn't allow gliding and axial shortening. Dynamically locked nails allow gliding and collapse at the fracture site. It is used only in diaphyseal fractures were cortical comminution is less than 50%.

Tibial nails are designed with proximal bow to facilitate easy insertion into the straight tibial canal. Usually hollow nails are used for tibia. Solid nails are also available. At present AO or GK nails are extensively used. AO nails have its **Herzog's bend** distal to Grosse-Kempf nail.

Reaming increases the contact between the nail and the cortical bone. When the nail is the same size of the reamer, 1mm reaming can increase contact area by 38%. Increased reaming allows insertion of larger nail which provide more rigidity.

Interlocking Nailing in Open Tibial Fractures

Currently intramedullary nailing has been recommended for even severe open fracture [48] of tibia. Reamed nailing is advised even for grade IIIB fracture[53].

Reamed Nailing Vs Unreamed Nailing

Intramedullary nailing after reaming [8,9,11,20] is now accepted as method of choice to treat open femoral fractures. But it’s controversial with open tibial fractures. But the recent studies have changed this view.

The vascular damage inflicted by reaming in association with the soft tissue injury has been thought to be increase the risk of infection and delayed union to an unacceptable level. The criticism that nailing after reaming is associated with high-rates of infection and nonunion is theoretical and is based on limited reports with small number of patients managed mostly with unreamed nails[54]. First Kaltenecker et al. and [33] then Court-Brown et al. (1991) have reported rates of infection, union and malunion compared very favorably with external fixation. He limits his nail size to 11 mm or less and advised to avoid tourniquet during reaming.

Keating et al. (1997) said although reaming damages endosteal circulation, it is not associated with increased risk of deep infection and nonunion.

The viability of the surrounding soft tissue, which supply nutrition to the bone & the body's ability to resist infection is the most important factor in fracture healing. Operative care of the soft-tissue wound is crucial in the management of open fractures.

The pluripotential mesenchymal cells that form fibrous tissue and eventually bone are thought to originate predominantly from surrounding tissue and from the cambial layer of the periosteum. The reaming process is likely to have little detrimental effect on this aspect of fracture-healing. The role of the endosteal circulation in fracture-healing may therefore be less critical than has been supposed.

Irrespective of whether the bone is reamed [26] or not, adequate debridement of the soft tissue and bone followed by excellent soft tissue coverage is the main step in minimizing the deep infection after these open injuries. Ziran et al. retrospectively reviewed and said reamed nailing decreases the need for secondary procedures.

Steven A Olson, in his instructional course lecture (JBJS 96) recommended unreamed nailing for open tibial fractures. He advised results of small unreamed nails with less stability (usually less than 8 or 9 mm) should be overweighed against larger nails with more stability but with increased risk of infection. JF Keating et al. (JBJS 2000) have shown good results with reamed nailing even for grade IIIB open tibial fractures.

Usually solid nails are used for unreamed nailing which decreases the dead space and the incidence of infection.

The disadvantages of the unreamed nail[43]

- Increased incidence of delayed union and nonunion of open fractures.
- The fatigue failure of the locking screws
- The choice of the correct length of the nail is difficult
- Axial alignment with the unreamed nail is difficult to achieve as the nail is a splint, has very limited contact with the endosteal bone.
- Limited applications in proximal and distal fractures.

Till date there is no consensus to recommend reamed or unreamed nailing. Definitive studies are underway.

But most of the authors recommend reamed nailing even for grade IIIB fractures.

PROCEDURE

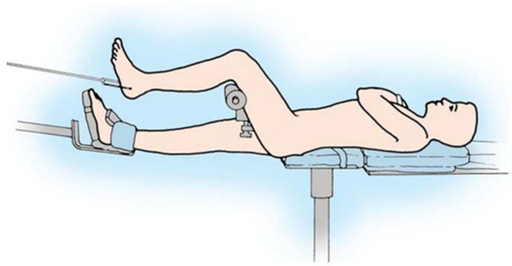
Position of the patient

In standard technique for interlocking nailing fracture table is used. Patient is kept in supine position with hip flexed to 45 degrees and knee flexed to 90 degrees under calcaneal pin traction. Patient may be positioned supine on the ordinary table with knees hanging down the end of the table or the knee kept in flexion with pillow under the knee.

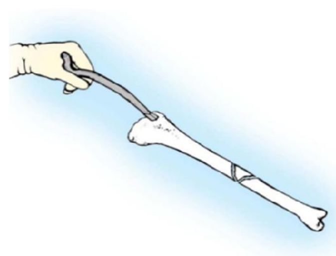
Fracture reduction

Fracture reduced by the traction through the calcaneal pin under C arm control. Calcaneal pin should be parallel to the ankle axis to avoid varus or valgus malalignment. When fracture table is not used fracture reduction done after insertion of guide wire and manipulation under C-arm or distractor may be used to reduce the fracture.

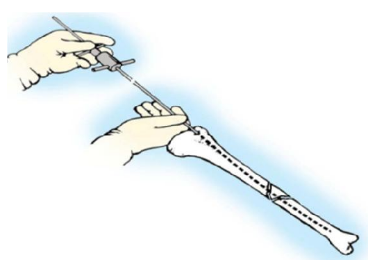
Positioning the patient



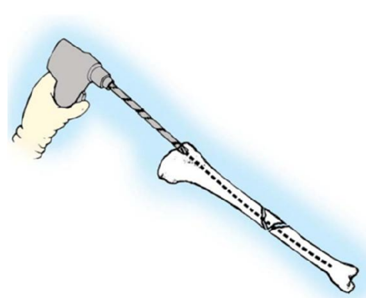
Awl entry



Guide wire insertion



Intramedullary reaming



Entry Point

Patellar tendon splitting approach

A vertical insertion from tuberosity to the lower end of the Patella is made. Patellar tendon is exposed and split in the middle. Entry point is made with awl, proximal to tibial tubercle approximately 1.5 cm distal to joint line and in line with the center of the medullary canal on the anteroposterior view. First awl is directed perpendicular to the shaft when it first penetrates the cortex, then gradually brought to more parallel to the shaft as it is inserted more deeply.

Medial Parapatellar approach

Here incision is made from middle of the medial border of patella to tibial tuberosity. Patellar tendon is exposed and retracted laterally. Entry point is made similar to the previous approach.

Fracture Reduction, Reaming and Nail Insertion

After entry point is made, guide wire is passed with image intensifier guidance. Guide wire should be in center of the distal fragment on both orthogonal X ray views and advanced to within .5 cm to 1 cm of ankle joint. Then, serial reaming done with 0.5 mm increments. Then flexible Teflon sleeve is passed over the ball tipped guide wire. Smooth tipped guide wire is used rather than ball tipped guide wire for nail insertion. Length of the nail determined by (Fluoroscopic measurement).

1. With the help of graduated guide wire.
2. Subtraction of the exposed guide wire from the total length of the guide wire.
3. Radio opaque ruler is useful to measure the distance between anterior edge of the entry portal to a point 0.5 to 1 cm proximal to ankle joint.

Nail diameter is selected 1 mm less than the last reamer used. Now the appropriate nail mounted in the Jig and it is inserted over the guide wire under C-arm control. The subchondral bone of the ankle joint, approximately 0.5 to 2 cm from the ankle joint line should be the position of the distal tip of the nail. Impaction of the fracture is achieved by releasing the traction. Proximally counter sinking of nail has to be done up to 0.5 to 1 cm to the proximal nail end to avoid anterior knee pain and early arthritis. Now the distal locking is done under C-arm control as free hand technique. Proximal locking is done with Jig. Before insertion of proximal locking fracture site is checked and if it is distracted reverse jamming is done.

Outcome assessment

There is no specific scoring system to analyze the outcome of open tibial fracture after fixing with interlocking nailing. Scoring derived from Karlstorm and olerud’s functional outcome assessment of tibial fracture of interlocking nailing.

Functional Evaluation System by Karlstrom-Olerud

Measures	**3 points**	**2 points**	**1 point**
Knee pain	No	Little	severe
Ankle pain	No	Little	severe
Difficulty in walking	No	Moderate	severe
Difficulty in stairs	No	Supported	unable
Difficulty in previous sportive activity	No	Some sports	unable
Limitation at work	No	Moderate	unable
Status of skin	Normal	Various colours	Ulcer/sinus
Deformity	No	Little	remarkable
Muscle atrophy	<1	1-2	>2
Shortening	<1	1-2	>2
Loss of motion at knee	$<10^{o}$	$10\text{-}20^{o}$	$>20^{o}$
Loss of motion at ankle	$<10^{o}$	$10\text{-}20^{o}$	$>20^{o}$

*36 points, excellent; 35-33 points, good; 32-30 points, satisfactory; 29-27 points, moderate; 26-24 points, poor

MATERIALS AND METHODS

This study was done from February 2012 – November 2013, for a period of 22 months, in The Institute of Orthopedics & Traumatology, Madras Medical College & Rajiv Gandhi Government General Hospital, Chennai. We did secondary interlocking nailing after preliminary external fixation for grade II to grade III B open tibia fractures in 31 patients for 31 fractures. Out of these 31 patients, we have lost follow-up of 4 patients and we have analyzed the results with the average follow-up of 12 months and minimum follow up of 5 months.

Inclusion criteria

- ❖ Any Gustilo and Anderson Grade II, III A and III B compound tibial fractures presenting to our institute within 48 hours of injury.
- ❖ Tscherne classification Grade I & 2.

Exclusion criteria:

- ❖ Patient presenting more than 48 hours of injury.
- ❖ Grade I and Grade III C open tibial fractures.
- ❖ Segmental fractures
- ❖ Medical co-morbidities like Diabetes, Renal disease.
- ❖ Patients treated by LRS, Plating, Ilizarov.
- ❖ Severe soft tissue wound / infection elsewhere in the body.

AGE INCIDENCE

Patients’ age ranged from 18 to 70 years. Average: 37

Age in yrs	No. of Patients
21 – 30	15
31 – 40	4
41 – 50	8
51 – 60	1
61 – 70	3
TOTAL	**31**

SEX INCIDENCE

In our series, Male predominated with the ratio of 9:1.

Sex	No. of Patients
Male	28
Female	3

MODE OF INJURY

In our series, RTA was the predominant cause of injury. In RTA, 2 wheeler Vs 6 wheeler was the most common (10 cases).

MODE	No. of Patients
RTA	25
Fall of heavy weight	2
Industrial	1
Assault	1
Buffalo stampede	1
Wood cutter injury	1

PLACE

In our series, nearly half (45%) of the patients were referred from other hospitals.

PLACE	No. of Patients
Chennai	17
Referred from outside Chennai	14

Referal time: Minimum of 1½ hour to the maximum of 45 hours.

SIDE

In our series, Right side was more common.

SIDE	No. of Patients
Right	18
Left	13

ASSOCIATED INJURIES / FRACTURES

In our series, 23% of the patients had Associated Injuries

Fractures / Injuries	No. of Patients
Head Injury	2
Posterior dislocation hip	1
Tibial plateau	1
Metatarsal fracture	1
Distal radius fractures	1

TIME DELAY TO SURGERY

In our series, average time to admission after injury was 9 hours (Minimum of 1½ hours to 45 hours). In cases referred from outside Chennai average time to admission after injury was 15½ hours.

In our series, average time from admission to surgery (External fixation) was 6½ hours (minimum of 1 hour to 14 hours).

In our series, total time delay from injury to surgery (Ext Fix) was 15½ hours.

For the patients referred from outside it was 23 hours.

CLASSIFICATION OF SOFT TISSUE INJURY:

We classified the open fractures of tibia according to the Gustilo and Anderson et al classification. Among 31 patients:

Grade	No. of patients
II	15
IIIA	12
IIIB	4
Total	**31**

ANATOMY OF FRACTURE

Type of Fractures	No. of Fractures
Transverse	8
Oblique	9
Comminuted	12
Segmental	1

In our series, nearly 40% of fractures were comminuted.

LOCATION OF FRACTURE

Tibia was divided into 4 quarters from A to D.

Location	No. of Patients
A (Proximal ¼)	1
B (Upper middle ¼)	14
C (Lower middle ¼)	11
D (Distal ¼)	4

In our series, most of the fractures were in middle half of the tibia.

TREATMENT PROTOCOL

On receiving the patients, we resuscitated them according to advanced Trauma life support guide lines in our Trauma ward. Patients were specifically examined for other associated injuries. Patients were hemodynamically stabilized. Injection Tetanus Toxoid was given to all of the patients. All the patients were given 2g of Cefatoxime at admission. Inj. Diclofenac and Inj. Pentazocine were used for pain relief.

Wound inspection & Classification

After temporary stabilization, wound was inspected and preliminary typing according to Gustilo and Anderson was made. Plastic Surgeon's opinion was obtained in all patients, in the initial wound examination itself.

If the wound is **clean,** wash with saline and betadine was done. Then sterile dressing and above knee slab was given.

If the wound is **contaminated** with external dirt, preliminary wound wash was given.

FLOW study

(Fluid Lavage of Open Wounds) standardize the minimum amount of soap or saline solution based upon the severity of open fracture wound according to the Gustilo-Anderson Classification

- Type I - 3 Litres,
- Types II and III - 6 Litres.

Sterile dressing and Thomas splint was applied. Inj. Tetanus anti globulin 500 I U was given in patients with gross contamination.

All patients were shifted for **investigations** after resuscitation and preliminary examinations. Good quality antero-posterior (AP) and lateral (Lat) X-Rays including knee and ankle were taken for the involved limb and other necessary

X-Rays were taken to rule out associated fractures. CT-Brain and Ultra-sound was taken in necessary patients.

EXTERNAL FIXATION

Patients were taken to operation theatre after preliminary anesthesiological assessment. At the time of starting anesthesia second dose of Inj. Cefatoxime was given to all of the patients. Dressing was opened in the theatre. Limb was prepared for surgery. Thorough wound debridement was done layer by layer after adequate extension of the wound. Fracture ends were debrided and freshened.

Loose fragments which were smaller and without soft tissue attachments were removed. Fragments with soft tissue attachments were retained as much as possible. Adequate irrigation was done with normal saline. After thorough debridement the wound grading was done as per Gustilo and Anderson method. Plastic Surgeon's opinion was sought in five cases during external fixation.

After ensuring thorough debridement, fracture was stabilized with external fixation to aid the wound healing and infection control.

All Grade II wounds were closed primarily.

All Grade III A wounds were closed primarily or split skin grafting was done. For Grade III B wounds flap cover [46] was done. 2 muscle flaps and 2 fasciocutaneous flaps were done with the help of plastic surgeons after third and fourth weeks of injury respectively.

POST OPERATIVE PROTOCOL FOR EXTERNAL FIXATION

All patients were started on injection Cefatoxime and Amikacin depending on the age and renal parameters. For Grade II and Grade III patients, appropriate antibiotics by culture and sensitivity were continued for 3weeks with ESR and CRP monitoring.

For Grade III B fractures, same antibiotics with Metrogyl was continued for 2 weeks. During dressing wound was inspected for signs of infection on every alternate day. Culture and sensitivity was done when there was any sign of infection and repeated every week when there was infection. Antibiotics were changed accordingly and were given for extended period of 3 - 4 weeks.

Post operative antero posterior and lateral X-Rays were taken to analyze the fragment alignment and their ends.

Once the wound got settled from infection by clinically, microbiologically and by serial monitoring of CRP & ESR.

Then patient is assessed for secondary intramedullary nailing.

Weight bearing was delayed for comminuted fractures and type III compound wounds for stable statically locked fractures weight bearing was started as soon as the patient tolerates.

All uncomplicated Grade II, Grade III A fractures & all Grade III B fractures were retained till adequate healing occurs. If the wound is healing and healthy with good alignment, external fixation was removed and patellar tendon bearing cast was given to ensure adequate knee mobilization for three weeks. Then planned for internal fixation with interlocking nailing.

INTERNAL FIXATION WITH INTRAMEDULLARY NAILING:

Careful patient selection was done with

- ❖ Clinically healed wound
- ❖ No growth in culture & sensitivity
- ❖ Normal ESR & CRP

Fracture pattern was carefully studied. Length of the nail was decided with Tibial tubercle – medial malleolar distance (TMD). The TMD is determined by measuring the length between the highest points on the medial malleolus and Tibial tubercle[4]. Diameter of the nail was determined with lateral X-Ray and according to the communition & segmentations.

Patients were taken to operation theatre after preliminary Anesthesiological assessment. Prophylactic antibiotic inj Cefotoxime 1gm IV was given to all of the patients 30 min before surgery. Limb was prepared for surgery.. Fracture ends were debrided and loose fragments were removed. Adequate irrigation was done with normal saline.

We used either split Patellar or medial para patellar approach (3 cases) for entry point identification. We reamed[8,9, 26-28] the medullary canal up to the measured nail size. Proximal locking was done with the help of Jig. Distal locking was done with either distal locking Jig or freehand technique under C-arm. Most of the cases distal locking is done with the jig and confirmed by the guide wire.

Out of 31 cases, 11 were open nailing and the rest 20 were closed nailing. Those which crossed 3 weeks of external fixation, had difficulty in closed nailing.

POST OPERATIVE PROTOCOL FOR INTERLOCKING NAILING

All patients were started on inj Cefatoxime and Amikacin depending on the age and the renal parameters. Same antibiotics were continued till suture removal. Post operative antero posterior and later X-Rays were taken and analyzed for nail length, locking and stability of the fixation. First look dressings were done on 3rd post operative day. Dressings were changed frequently whenever there was soakage. After that dressings were changed on alternative days. During dressing wound was inspected for signs of infection like warmth, swelling, skin induraion, and bulging of the sutured ends.

Culture and sensitivity was done when there was any sign of infection. Culture and sensitivity was repeated every week when there was infection. Antibiotics were changed accordingly and were given for 4 – 6 weeks.

We started **static quadriceps exercise** and toe movements on the second post operative day. **Knee mobilization with quadriceps exercise** started as soon as the pain subsides.

Weight bearing was delayed for comminuted fractures and type III compound wounds for stable statically locked fractures weight bearing was started as soon as the patient tolerates. Partial weight bearing was started for Grade III and comminuted fractures once the callus formation was seen.

All uncomplicated Grade II and Grade III A, fractures were discharged after second look dressing (POD - 4) of the wound. All complicated and Grade III B fractures were retained till adequate healing occurs and the wound is inspected on every day.

Follow-Up

We advised

- Static/ Dynamic quadriceps exercise & knee mobililsation - started as soon as pain is tolerated
- Suture removal on 12th day.
- Monthly follow-up for first 3 months.

- Every 3 months up to union and every six months afterwards.
- Weight bearing - not allowed since radiological and clinical evidence of union is achieved

Each follow-up patient were examined for

- Knee / Ankle pain
- Tenderness at the fracture side
- Signs of infection Joint motion
- Radiological assessment of union.
- **Union** was defined as presence of 3 cortical callus on two radiographic views with complete absence of pain on walking.
- **Delayed Union**[5] A failure to see evidence of union on radiographs at various time-points ranging from twenty to twenty-six weeks.
- **Nonunion**[20] A fracture that occurred a minimum of nine months back and has not shown radiographic signs of progression toward healing for three consecutive months.
- **Infection**[5] was defined as a purulent discharge from which organisms were grown.
- **Malunion**[5] was defined as more than 1 cm of lengthening or shortening or more than 5^{o} of rotational or angular deformity.

OBSERVATION & RESULTS

Type II Fractures

Union was observed in 11 of the 13 patients. The mean time to union was 27 weeks (range 20 weeks to 40 weeks). Dynamisation alone was done in one patient. Dynamisation followed by bone grafting was done in other patient. For infective non union seen in one patient, posterolateral bone grafting was done and for non union in other patient bone grafting was done. Results of these patients were awaited. No patients had undergone implant exit and LRS, Ilizarov after nailing

Type III A Fractures

Union was observed in 7 of the 10 patients. The mean time to union was 31 weeks (23-37 weeks). Prophylactic bone grafting was done in 1 patient. Aseptic nonunion was seen in one patient in which bone grafting[13] was done. Infective non union was seen in two patients, for which antibiotic exchange nailing has been planned.

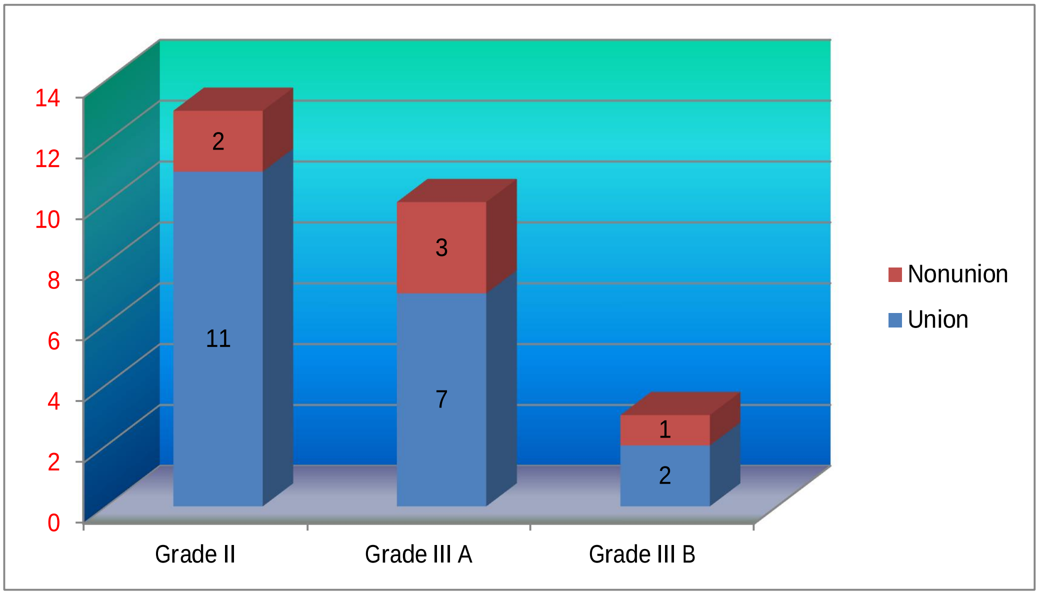
Type III B Fractures

Two of the four type III B fractures united in average time of 47 weeks. Out of the 4 patients muscle flaps was done in 2 patients and fasciocutaneous flaps in 2 patients. 3 patients developed infection, for which appropriated antibiotics were given. One patient required wound debridement. Dynamisation was done in 1 patient. Union achieved in 1 infected patient following posterolateral bone grafting. Wound debridement and bone grafting was done in 1 patient and wound debridement, antibiotic coated exchange nailing with bone grafting in 1 patient. Results are awaited for the 2 patients.

We assessed the outcome with Karistorm-Olerud criteria

Grade	No.of Cases	Union	Dynamisation	Bone Graft	Time (Wks)	Deep Infection	Non Union	Aseptic Non Union
II	13	11	2	3	27	1	1	1
IIIA	10	07	1	1	31	2	2	1
IIIB	04	02	1	3	47	3	2	-
Total	27	20	4	7	35 (Average)	6	5	2

Union rate (No. Of Union & Nonunion)



COMPLICATIONS

Early

- Alcoholic delirium developed in three patients. They were treated with

  I.V.Fluids and diazepam.
- Fasciocutaneous flap necrosis occured in two patients
- Superficial infection was seen in five patients.
- Split skin graft necrosis occurred in one Grade IIIA patient and one Grade IIIB patient which were allowed to granulate because of superficial infection.

Late

- Deep infection developed in six patients (Grade II-1, Grade IIIA – 2, Grade IIIB – 3) and all developed Non-union.
- Aseptic Non-union in two patients.
- Ankle stiffness in 1 patient and movement restriction was noted in 3 patients.
- Anterior knee pain was observed in 4 patients.
- Hyper pigmentation of flap was noted in 2 patients.

DISCUSSION

External skeletal fixation has become the established treatment for severe open tibial fractures despite the problems of malunion and pin-track sepsis associated with its use. In early years intramedullary nailing using unreamed unlocked nails had produced good results in type III open tibial fractures but the method did not adequately stabilize comminuted or segment fractures. Then reamed interlocking nailing (J.F.Keatings Et al) have become the answer for this without increasing the rate of infection. Recently treatment for open tibial fractures have evolved into a stage where primary nailing and immediate/early soft tissue cover[49] became the prime method of treatment.

In our hospital immediate wound debridement with or without external fixation and cast immobilization followed by elective interlocking nailing is the routine for grade I and grade II open tibial fracture. Wound debridement and External fixation followed by repeat wound debridement after 72 hours and elective delayed primary cover followed by internal fixation is the method of treatment for grade III fractures.

The timing of secondary intramedullary nailing in our study shows that Grade II open fractures were undergone nailing with average of 11.8 days with the range of 6 -20 days. Grade III A fractures have undergone nailing with average of 30 days with the range of 14 – 48 days. For grade III B fractures nailing was done with the average of 32.5 days ranging from 28 – 45 days.

We have done 31 cases out of which we have lost the follow up of 4 patients. We have analyzed union, infection and functional outcome in the remaining 27 patients. In our study average time to union was 35 weeks (grade II – 27 wks, grade IIIA – 31 wks, grade IIIB - 47 wks)

Grade II fractures results were comparable with the previous studies (Averaging 23.5 wks in Court-Brown et al).one required dynamisation and another required dynamisation and bone grafting.

Grade III fractures union time is comparable with the previous studies.

One Gr III A and one GrIII B patient had bone grafting. Dynamisation was done in one GrIII B patient.

Author	**Treatment**	**UnionTime(wks)**	
		III A	**III B**
Blick et al (1989)	External fixation	38.6	47
Court-Brown et al (1990)	External fixation	26.5	47.4
Court-Brown(1991)	Intramedullary Nailing	27.2	50.1
Our study	**External fixation and secondary Intramedullary Nailing**	**31**	**47**

Comparing with Blick et al, Court-Brown et al, our union rate was on par with other studies. Infection was noted in 6 patients, 5 were early infections (Gr II- 1, GrIII A-2 and GrIII B-3) and one (GrIII A) being late. . Three of them were (Gr II-1,GrIII A- 1, GrIII B-1) taken up for external fixation after twenty four hours and all of them were referred from places outside Chennai. Probably this delay in initiating the treatment could have been the reason for infection. Two of the three Gr III compound fractures developed infection following flap necrosis.

Study	**Treatment**	**Union (Wks)**	**Infection (%)**
Our study	**External fixation with Secondary Interlocking nailing**	**39**	**35**
Blick et al (1989)	External fixation	45.2	9.5
Court-Brown (1990)	External fixation	36.7	17.6
Court-Brown (1991)	Intramedullary nailing	38.2	11.1

Infection rate following sequential nailing

Study	**Infection**	**Non union**
Megraw et al 1988	44%	54%
Maurer et al 1989	25%	35%
Our study	**35%**	**26%**

Comparing the other studies the infection rate following sequential nailing was comparable or better. Non union developed in 7 patients out of which 2 being aseptic nonunion. These two aseptic nonunion were diagnosed to have delayed union for which bone grafting was advised but the patients were not willing to undergo any procedure at that time. Bone grafting was done in these two patients later after a trial of dynamisation.

Study	Treatment	Nonunion (%)
Our study	**External fixation with secondaryInterlocking nailing**	**26%**
Clifford etal. 1997	External fixation and delayed cover	23.8%
J.F.keatings etal.1997	Primary interlocking nailing and delayed cover	12%
Sanders etal. 1994	Primary interlocking nailing & delayed cover	17%.

In our study nonunion rate was similar to the external fixation group but morbidity associated with external fixator was there. On comparing with other studies, high rate of nonunion was due to delay in secondary intervention. In 5 out of the 7 cases secondary intervention has been done and results are awaited . Though there is high rate of nonunion, functional outcome assessment by Karlstrom & Olerud score was excellent to satisfactory in 25 patients and poor in only two patients.

Anterior knee pain[25] was noticed in four patients but all of them were done through medial Para-patellar approach.

CONCLUSION

Primary interlocking and primary closure produces excellent results in GrI and GrII fractures as compared to any other modality of treatment.

Primary interlocking nailing and primary closure as a single staged procedure required less number of secondary procedures as compared to external fixation and secondary nailing.

Due to various reasons like delayed referral, heavy contamination with road traffic accidents, emergence of multi resistant organisms, the compound wound requires thorough wound debridement, multiple liberal and repetitive wound wash with skeletal stabilization by external fixation.

Functional outcome of secondary intra medullary nailing after external fixation was far better than in primary interlocking with primary closure in our institution.

The average days for secondary intramedullary tibial nailing after external fixation for Grade II, Grade III A and Grade III B were 11.8, 30, 32.5 days respectively.

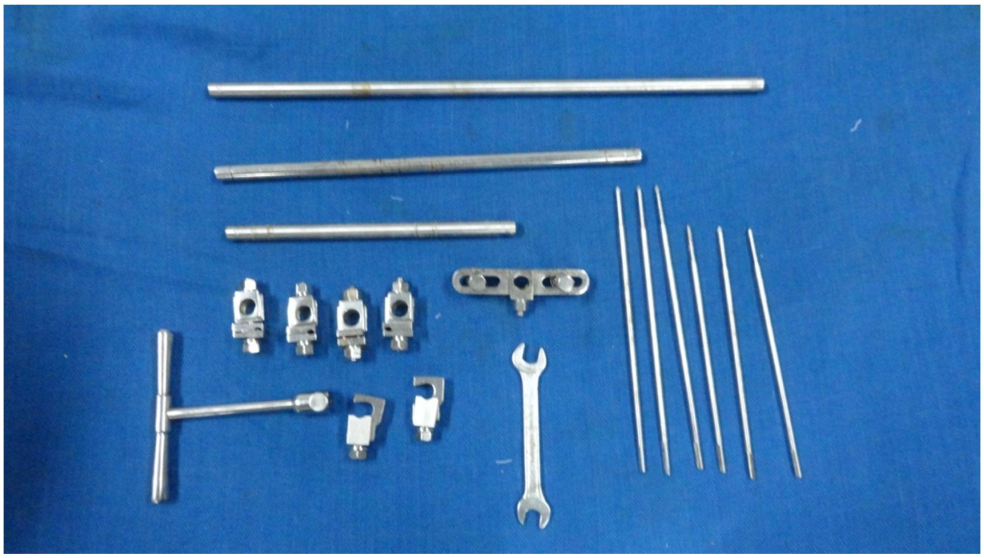
Although the superficial infection is there and there is delay in definitive procedure in the management of compound fractures, this can be improved by early surgical intervention, timely secondary procedures and accurate assessment of soft tissue injury.

The final outcome is mainly depends on the age of the patient, time of admission since injury, type of injury. Good result is favored by the debridement technique, appropriate selection of timing for external fixation and intramedullay nailing.

Early intervention and aggressive soft tissue management in open tibial fractures result in decreased number of procedures, minimal hospital stay and early return to their daily routine.

INSTRUMENT SET

EXTERNAL FIXATION IMPALNTS



TIBIA NAILING SET

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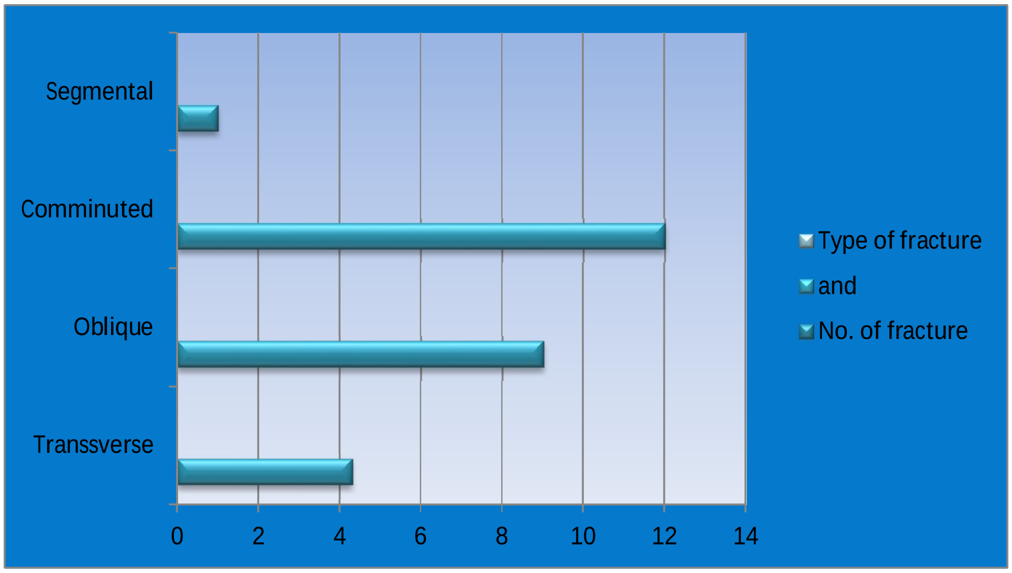
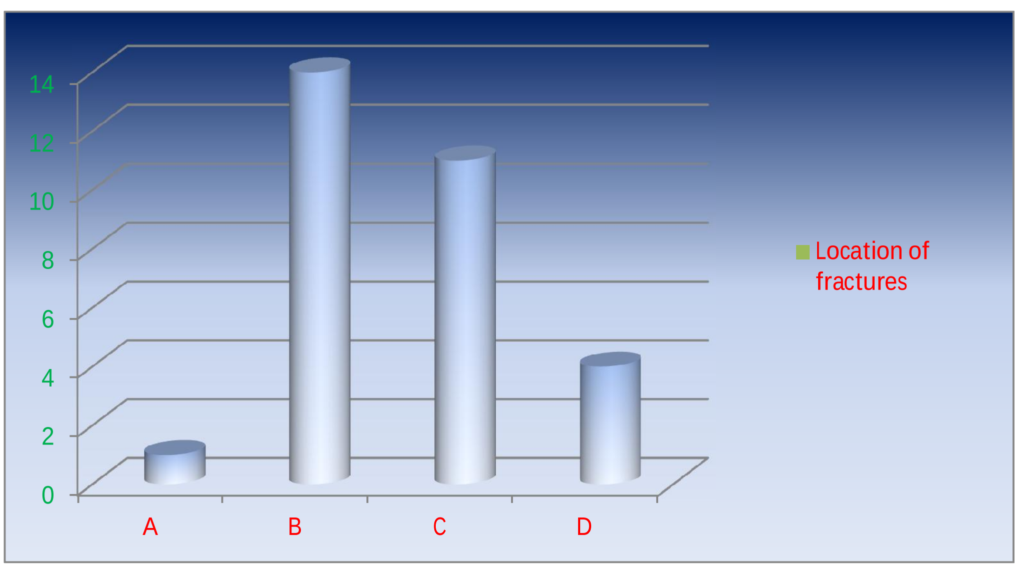
CHARTS

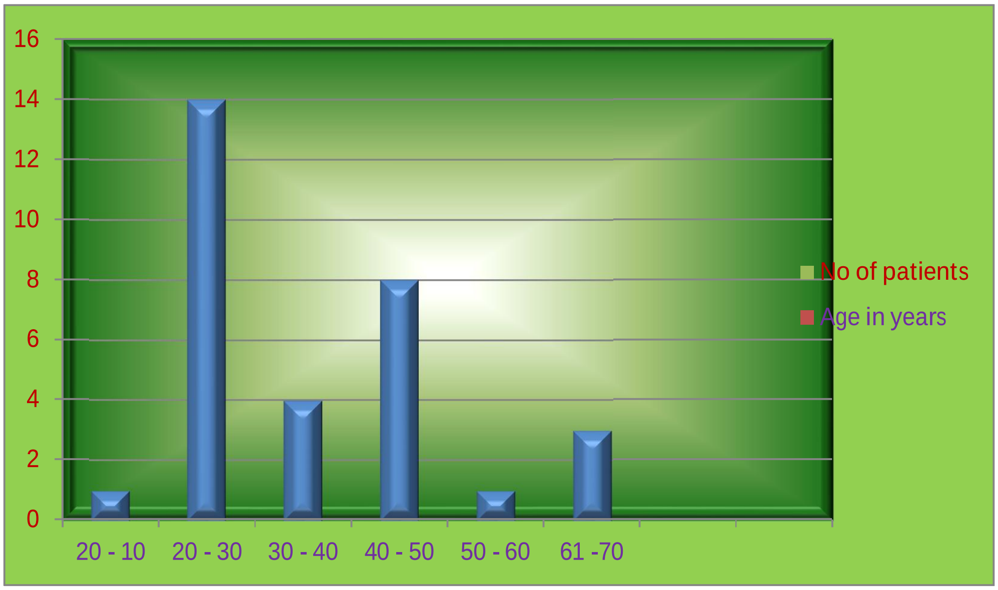
Anatomy of the fracture



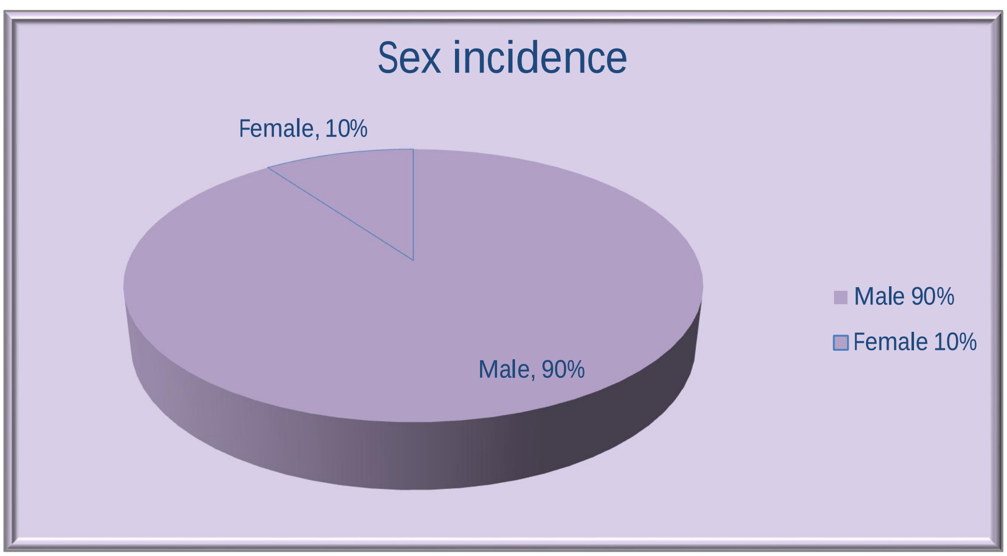
Number of fracture & its location.



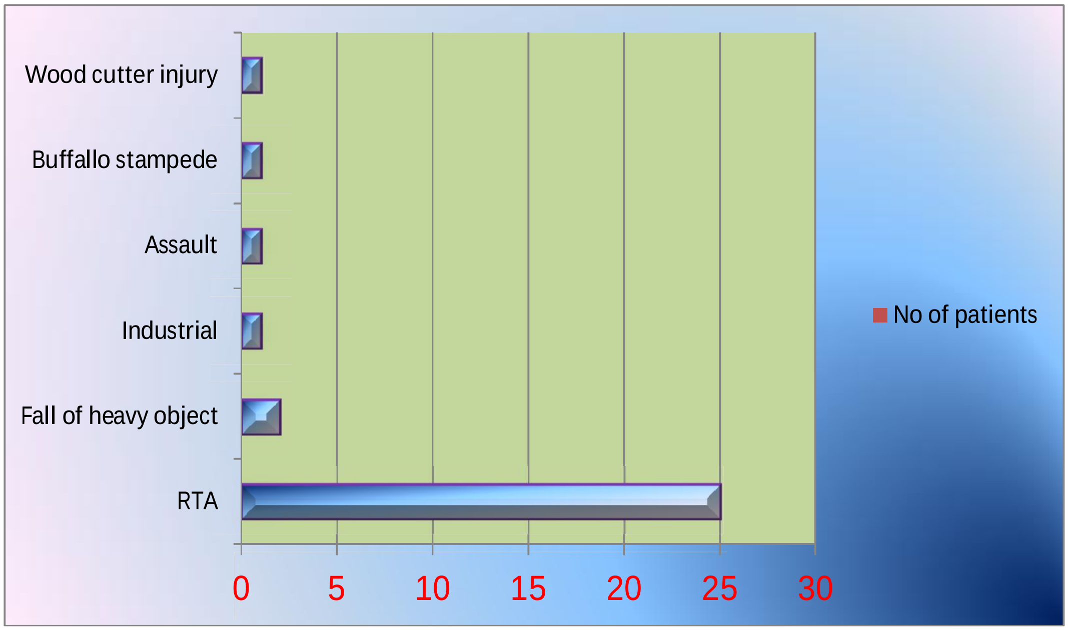
Age incidence



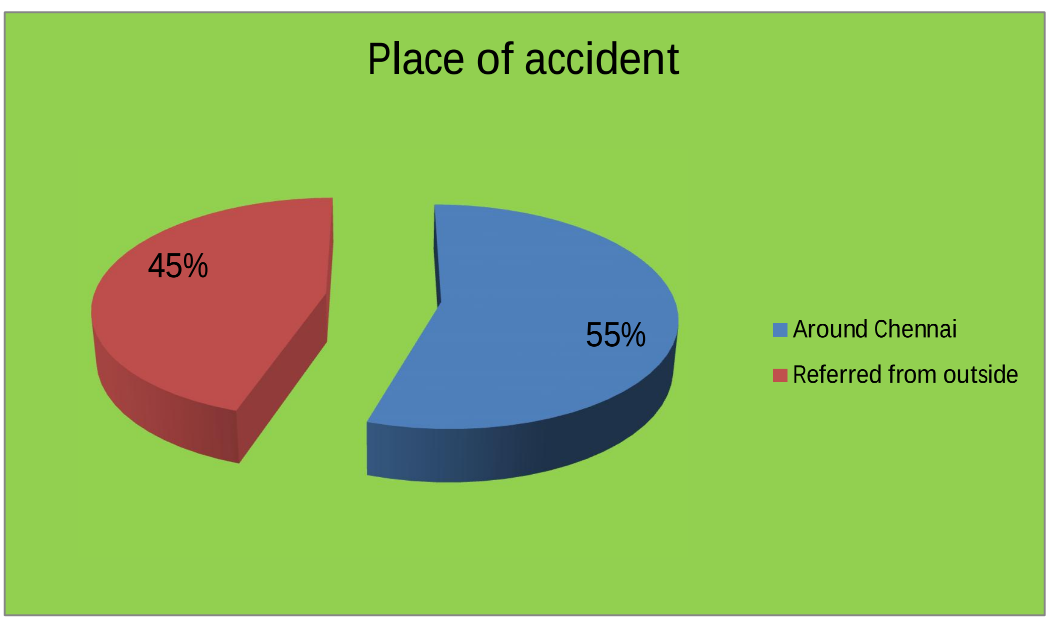
Sex Incidence



Mode of injury

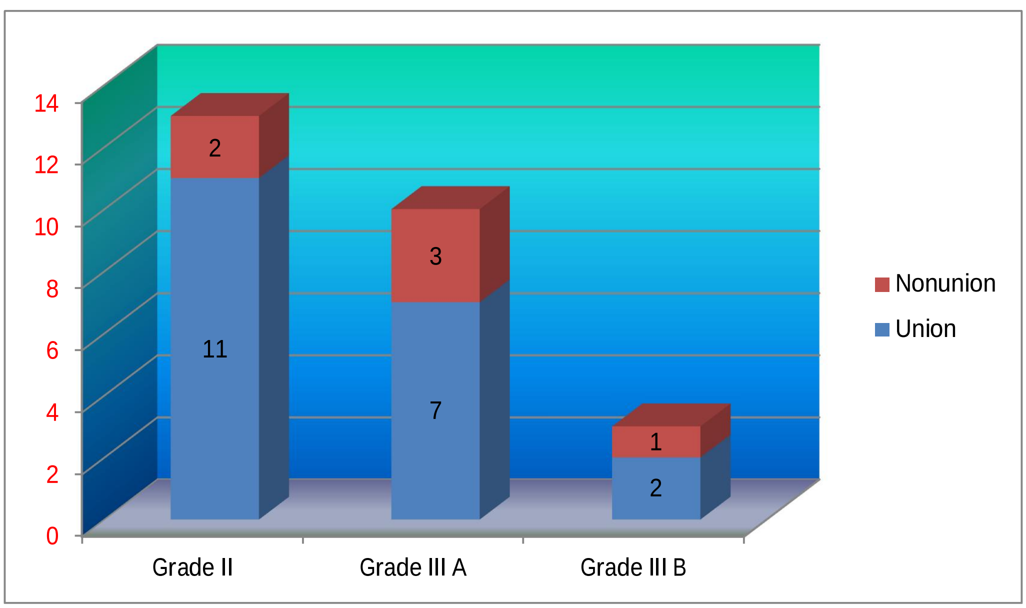


Place of accident



Average Timing of secondary nailing after external fixation

Union rate (Union Vs Non union)



ANNEXURE

Patient's evaluation form

Serial number :

Name : Age/Sex :

IP No :

Address : Phone No :

Mechanism of injury :

Place of injury :

Associated factors influencing injury :

H/O Epilepsy/

Alcoholism :

Any other consumption :

Time of presentation :

Associated General

Illness : DM/HT/Any other :

Type of fracture :

Open: Grade of fracture: II / III A / III B

Associated other injuries:

Vascular / Nerve injury / Crush injury of foot / Metatarsal fractures / Calcaneal fractures / Pelvic & sacral injury.

Time of presentation :

Injury to Admission (Hrs):

Time of wound debridement & external fixation:

Type of external fixation :

Time delay :

Time of intramedullary nailing :

Nail size :

Open Nailing : O

Close Nailing : C

Soft tissue cover :

- SSG /Flap cover :

Soft tissue complications :

Infection

- No infection
- Superficial infection
- Deep infection

Non union :

- Absent
- Aseptic nonunion
- Infective nonunion

Secondary procedure :

- Dynamization
- Bone grafting

Follow up :

- Month
- Visit

Union score :

- Poor - Good
- Satisfactory - Excellent

Case No. 1

25 year Male, RTA, Grade II fracture

On Admission

After External Fixation



After PTB Cast & External fixation removal



After Intramedullary Nailing

After 6 Months Follow Up

After 6 Months Follow Up - Excellent

Case No .2

23 year Male,RTA,Grade III B fracture

At Admission

After Wound Debridement & External fixation

After PTB Cast With Window.

After intramedullary nailing

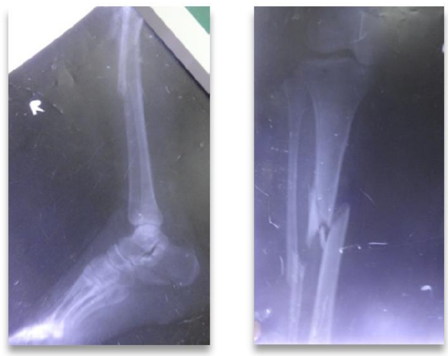
After 6 month follow up

Functional outcome: Excellent

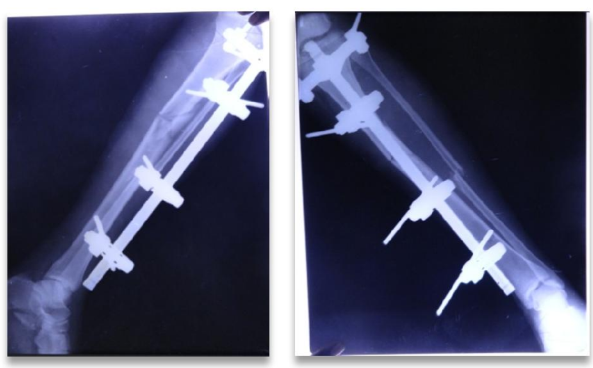
Case No .3

23 year female, RTA, Grade III Fracture

At Admission



After Wound Debridement & External fixation



Post operative x rays 18 months follow up & Post dynamisation:

18 months follow up clinical outcome:

Functional Outcome: Excellent

Case No.4

30 year male, RTA, Grade III B Fracture with Left Hip

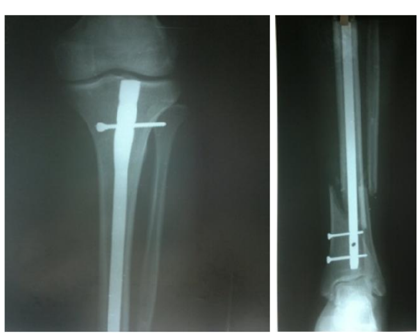
Posterior Dislocation

At Admission

After wound debridement & External fixation

After intramedullary nailing

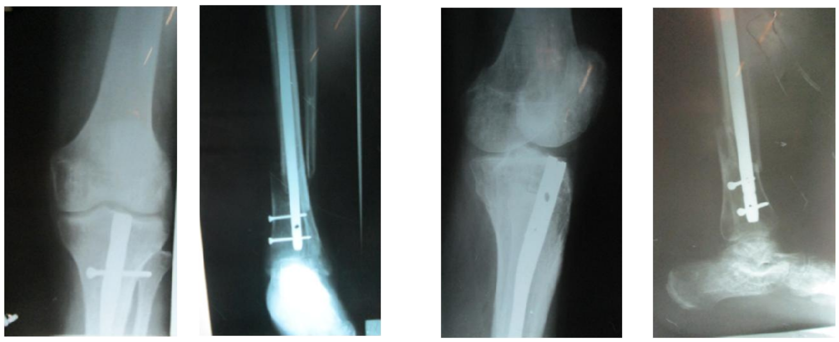
Anteroposterior



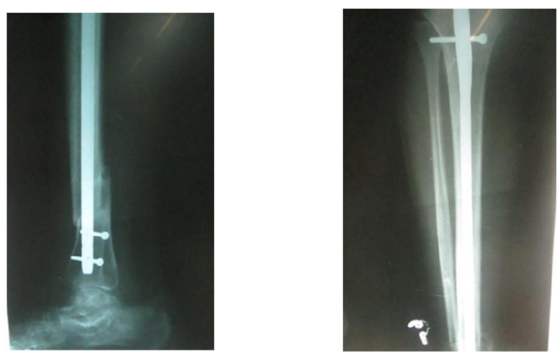
Lateral

5 months follow up

AP Lateral



7 months follow up



Functional outcome – excellent

Case No :5

42year male, fall of heavy weight, Grade III B fracture

On Admission

Wound debridement & External frixation,

Fasciocutaneous flap

Interlocking nailing

1year follow up- union after posterolateral bone grafting

Functional outcome: Excellent

MASTER CHART

S.No	Name	IP.No	Age/Sex	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Vanitha	3977	25/F	1	2	20	12	32	24	GIIIA	32X8-**C**	1	0	0	0	0	0	Lost	---
2	Karthik	4771	27/M	2	1	2	3.25	5.25	33	GIIIA	36X9-**C**	1	0	0	0	0	0	22/4	3
3	Narayanan	69327	43/M	1	2	3.75	7.25	11	35	GIIIA	34X9-**O**	1	0	0	0	0	0	20/2	2
4	Selvam	44068	30/M	1	1	3	8	11	47	GIIA	38X10**C**	1	0	0	0	0	0	Lost	---
5	Gubendran	13996	23/M	1	2	3.75	9.75	13.5	45	GIIIA	34X9-**O**	1	0	0	0		0	13/2	3
6	Jegan	53005	22/M	1	1	2.5	3.5	6	42	GIIIA	32X8-**O**	1	0	0	0	1	1&2	15/3	2
7	Shanmugam	92294	18/M	1	2	15	7	22	8	GII	32X8-**C**	1	0	0	0	0	0	15/5	3
8	Rajagopal	45736	42/M	5	1	1.25	3.25	4.5	36	GIIIB	32X9-**O**	2	1	1	1	0	1	14/2	2
9	Arujnan	54747	49/M	1	1	3	7	10	32	GIIIA	32X9-**O**	3	0	0	0	0	0	14/6	2
10	Mani	46388	49/M	3	2	43	8	51	21	GIIIB	34X8-**C**	4	0	0	1	1	1	1/11	1
11	Azhaguvel	75201	43/M	1	1	3.25	1	4.25	7	GII	36X9-**C**	1	0	0	0	0	2	14/5	3
12	Shankar	33569	70/M	1	2	2.75	9	11.75	28	GIIIA	34X9-**C**	1	0	0	0	0	0	Lost	---
13	Abdullah	47743	38/M	1	2	12.25	125	24.75	10	GII	32X9-**C**	1	0	0	0	0	0	Lost	---
14	Selvaraj	16960	42/M	1	1	4	12	16	12	GII	34X9-**C**	1	0	0	0	0	1&2	13/5	3
15	Saiful	62885	34/M	1	2	6	4	10	45	GIIIB	36X9-**O**	2	1	1	1	1	1	13/5	0
16	Samundi	114432	60/F	1	1	4.5	4.25	8.75	18	GIIIA	30X9-**C**	1	0	0	1	1	0	5/12	0
17	Rajasekar	76872	32/M	1	2	45	6	51	20	GII	34X9-**C**	1	2	1	1	1	1	3/11	1
18	Prakash	22777	30/M	1	1	4	8.25	12.25	28	GIIIB	36X9-**O**	5	0	0	0	0	0	6/11	2
19	Ivor Richard	28634	22/M	1	1	7	1.5	8.5	10	GII	32X9-**C**	1	0	0	0	0	2	3/12	3
20	Murugesh	31980	25/M	1	2	17.75	5.25	23	12	GII	34X8-**C**	1	0	0	0	0	0	3/10	3
21	Danammal	38171	70/F	1	1	2.75	5	7.75	9	GII	30X9-**C**	1	0	0	0	0	0	6/12	2
22	Karthikeyan	33086	23/M	1	2	4.75	4	8.75	6	GII	34X8-**C**	1	0	0	0	0	0	4/1	3
23	Veera	46405	25/M	1	1	3.5	4	7.5	8	GII	36X9-**C**	1	0	0	0	0	0	3/1	3
24	Anandaraj	30933	30/M	4	2	12.75	13.75	26.5	16	GII	36X9-**C**	1	0	0	0	0	1	3/10	1
25	Mariappan	73564	28/M	4	1	1.75	3.5	5.25	14	GIIIA	38X9-**O**	3	3	1	1	1	0	2/10	3
26	Kulbakkar	71643	40/M	1	1	2	4	6	30	GIIIA	36X9-**O**	1	0	0	0	0	0	2/8	1
27	Theeran	83323	23/M	1	1	4	6	10	47	GIIIA	32X8-**O**	1	0	0	0	0	0	2/7	2
28	Sekar	15580	43/M	1	1	12	14	26	15	GII	32X8-**C**	1	0	0	0	0	0	2/7	2
29	Madivanan	30899	23/M	1	1	4	6	10	22	GIIIA	34X9-**C**	1	0	0	0	0	0	2/6	2
30	Manickkammal	16925	65/F	6	2	16	8	24	28	GIIIA	32X8-**C**	1	0	0	0	0	0	2/5	2
31	Dandapani	39629	45/M	1	2	12	3	15	16	GIIIA	32X10**O**	1	0	0	0	0	0	3/5	2

Key to Master Chart

A	-	Mode of injury
B	-	Place of injury
C	-	Injury to Admission (Hours)
D	-	Admission to external fixation
E	-	Time delay
F	-	External fixation to Intramedullary nailing
G	-	Grade of the injury
H	-	Nail size (cm x mm). C- Closed nailing, O – Open nailing
I	-	Soft tissue cover.
J	-	Soft tissue complications.
K	-	Superficial infection.
L	-	Deep infection.
M	-	Non union.
N	-	Secondary procedure.
O	-	Follow up (Month/visit).
P	-	Union score.

Mode of injury: (A) 1 – RTA 2 – Industrial injury 3 – Wood cutter injury 4 – Buffalo hit 5 – Fall of heavy object 6 – Assault	**Superficial infection: (K)** 0 – Absent 1 – Present
Place of injury: (B) 1 – Chennai 2 – Outside	**Deep infection : (L)** 0 – Absent 1 – Present
Grade: (G) 1- Grade II 2- Grade III A 3- Grade III B	**Non union**: (M) 0 – Absent 1 – Aseptic Non union 2 – Infective nonunion
Soft tissue cover: (I) 1 – Closure 2 – Fascio cutaneous flap 3 – Split skin graft 4 – Gastronemius falp 5 – sural flap	**Secondary procedure: (N)** 1 – Bone grafting 2 – Dynamisation
Soft tissue complication: (J) 1 – fascia necrosis 2 – Skin necrosis 3 – SSG necrosis	**Union score: (P)** 0 – Poor 1 – Satisfactory 2 – Good 3 – Excellent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